NCC9-16

NASA-CR-194487

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PROCEEDINGS

Real-Time Simulation Development for Aerospace Applications

Requirements Generation: System's View

November 7, 1989

University of Houston-Clear Lake
Bayou Building 1-311

Co-Sponsored by:

NASA/ Johnson Space Center
University of Houston-Clear Lake

(NASA-CR-194487) REAL-TIME SIMULATION DEVELOPMENT FOR AEROSPACE APPLICATIONS. REQUIREMENTS GENERATION: SYSTEM'S VIEW (Houston Univ.) 71 p

N94-70075

Unclas

Z9/61 0193091

J4

ATTENDEES FOR Nov. 7 "Real Time Simulation"

Bates	Freurick	Barrios	1881 Gemini
Jacobs	Rebecca	Barrios	1331 Gemini, DC 36
Price	Lonnie	Barrios	1331 Gemini MC: B30/DC36
Smith	Tacy	Barrios	MC: DG53
Weisman	Melanie	Barrios	MC: DG53
Connelly	Donald	Bendix	501 Gemini, B24L-555
Gresham	Doug	Bendix	555 Gemini Ave. MC: B24E-555
Shipp	Reid	Bendix	501 Gemini
Anderson	Phil	CAE Link	
Baston	Jack	CAE Link	2224 Bay Area Blvd.
Birch	Eric	CAE Link	2224 Bay Area Blvd.
Henderson	JoAnne	CAE Link	2224 Bay Area Blvd.
Hershey	Lynn	CAE Link	
Kidwell	Harlan	CAE Link	2224 Bay Area Blvd.
Kumpunen	Hank	CAE Link	2224 Bay Area Blvd.
Matulnes	M.J.	CAE Link	2224 Bay Area Blvd. MC: BE2
McFadden	Reginald	CAE Link	2224 Bay Area Blvd.
McNair	Barnie	CAE Link	
Parlinti	Joe	CAE Link	2224 Bay Area Blvd.
Plum	Rick	CAE Link	2224 Bay Area Blvd.
Sharkey	Martha	CAE Link	
Strathmeyer	Audrey	CAE Link	2224 Bay Area
Townsend	Hal	CAE Link	
Turner	Seymour	CAE Link	
Urqhart	Roy	CAE Link	2224 Bay Area Blvd.
Watts	John	CAE Link	2224 Bay Area Blvd.
Wessale	Bill	CAE Link	2224 Bay Area Blvd.
Williams	Oscar	CAE Link	
Brown	Gretchen	Draper	2200 Space Park
Bartholomew	Mike	Evans & Sutherland	580 Arapeen Dr.
Howes	Ralph	Evans & Sutherland	580 Arapeen Dr.
Ackerman	Elizabeth	GHG Corporation	1300 Hercules, Suite 111
Hossain	Sabbir	Lockheed	2400 NASA Rd. 1 MC: C50
Kell	Ted	Lockheed	
Kirkham	Roberta	Lockheed	2400 NASA Rd. 1
Lively	Fred	Lockheed	2400 NASA Rd. 1 MC: C32
Rando	I.G.	Lockheed	2400 NASA Rd. 1
Schindeler	Rita	Lockheed	2400 NASA Rd. 1 MC: C18
Street	E.A.	Lockheed	2400 NASA RD 1 C18
Yuen	Vincent	Lockheed	2400 NASA Rd 1 MC83
Wierzbicki	John	Lockheed Engr./Sci.	2400 NASA Rd. 1
Haas	Fran	Lockheed Engr/Scienc	2400 NASA Rd. 1 MC: B08
Schaller	Rob	Lockheed Engr/Scienc	2400 NASA Rd. 1 MC: B08
Fugate	Bryan	MCC	9390 Research Blvd.
Giusti	Ron	MITRE	1120 Nasa Rd. 1, MC: MITRE/F
Cernosek	Gary	McDonnell Douglas	16055 Space Center MC: TB2
Kohn	Dale	McDonnell Douglas	16207 Space Center
Slaughter	Bill	McDonnell Douglas	1300 Bay Area Blvd., MC-T4G
Warner	Darrell	McDonnell Douglas	16500 Space Center
Brown	Rochelle	NASA/JSC	DC331
Burke	Bill	NASA/JSC	
Crouse	Ken	NASA/JSC	
Dahms	Denis	NASA/JSC	
Graham	Susan	NASA/JSC	MC: FS9
Henderson	Tom	NASA/JSC	DC331
Holkan	Robert	NASA/JSC	
Jordon	Keith	NASA/JSC	
Lauritsen	Janet	NASA/JSC	MC: FS9
ilhoan	Jerry	NASA/JSC	
arson	Barbara	NASA/JSC	MC: DG53
emeyer	Kelly	NASA/JSC	DC441

Roundtree	Dick	NASA/JSC	
Sylvester	Andre	NASA/JSC	MC: EF311
Sylvester	Andy	NASA/JSC	MC: EF3
Troung	Vi	NASA/JSC	MC: EF311
Ward	Dawn	NASA/JSC	
Constantinides	Lenna	Rockwell	600 Gemini MC: R16G
Moyer	Philip	Rockwell	600 Gemini MC: R14A
Pantazis	Mike	Rockwell	600 Gemini, MC: R11C
Smith	Tina	Rockwell	600 Gemini
Thompson	David	Rockwell	600 Gemini MC: R16C
Ziegelmair	Lud	Rockwell	600 Gemini MC: R11A
Golas	Dr.Katharine	Southwest Research	P. O. Drawer 28510
Montag	Bruce	Southwest Research	P.O.Drawer 28510
Ratcliff	Shirley	Southwest Research	P.O.Drawer 28510
Humbert	Mark	UNISYS	600 Gemini MC: U09A
Kayser	Fred	UNISYS	600 Gemini U01B
Masters	Sylvia	UNISYS	600 Gemini MC: U05C
Phung	T.	UNISYS	600 Gemini MC: U07B-16
Rogganbuck	Jim	UNISYS	600 Gemini U01B
Saha	H.	UNISYS	600 Gemini MC: U07A
Wells	Karen	UNISYS	600 Gemini MC: U09A
Gardner	John	Unisys	600 Gemini MC: U09A

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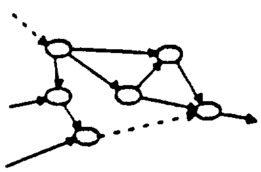
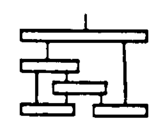


Attempts at Object-Oriented Requirements Analysis Using Traditional CASE Tools



NOVEMBER 7, 1989

A. Strathmeyer
713-488-5510

Link Flight Simulation Division
of CAE-Link Corporation

Agenda

- The OOD/Ada Validation Project
- Why Do Object-Oriented Requirements Analysis?
- What Is A "Traditional" Case Tool?
- Merging The Two: Our Four Attempts

Attempts at Object-Oriented Analysis Using Traditional Case Tools

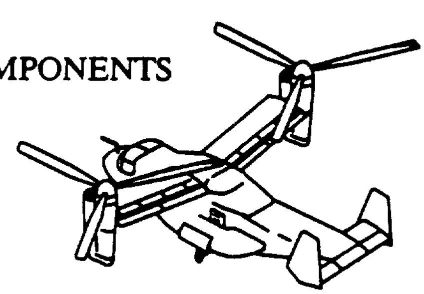
The OOD/Ada Validation Project

GOALS:

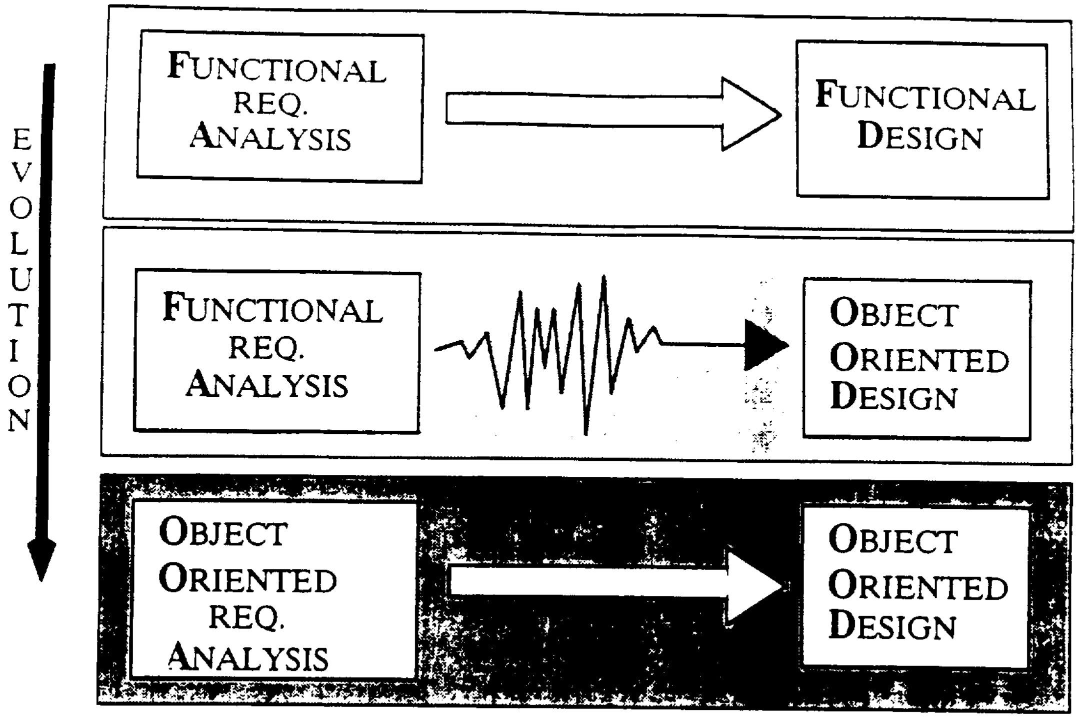
- APPLY OBJECT-ORIENTED METHODOLOGY TO A PROJECT
  - -- INCLUDING REQUIREMENTS ANALYSIS
  - -- USED DERIVITIVE OF MV-22 SPECIFICATIONS (SRS, IRD)
  - -- START AFTER SYSTEM DESIGN REVIEW THROUGH SWI
- MAKE USE OF EXISTING TOOLS
- ADHERE TO DOD-STD-2167A
- PRODUCE REUSABLE ADA COMPONENTS

SUPPORT:

- STARTED IN 1987
- FUNDED BY IR&D
- STAFF RANGED FROM 4 TO 10



Why Object-Oriented Analysis?

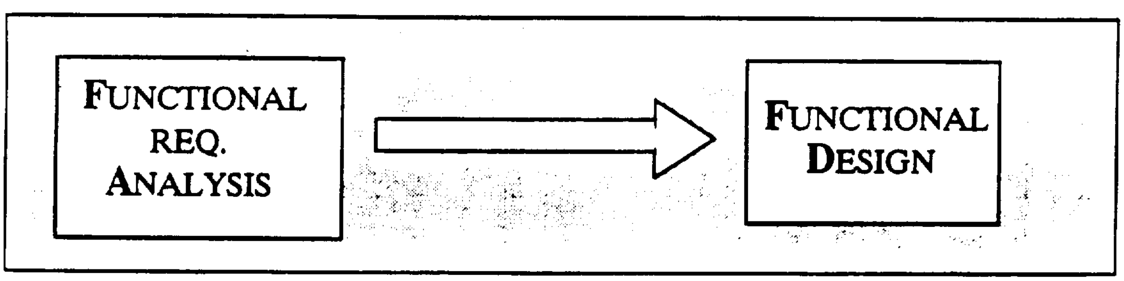


Object-Oriented Analysis -- Why?

TRADITIONAL TECHNIQUE

SMOOTH TRANSITION

TRADITIONAL TECHNIQUE

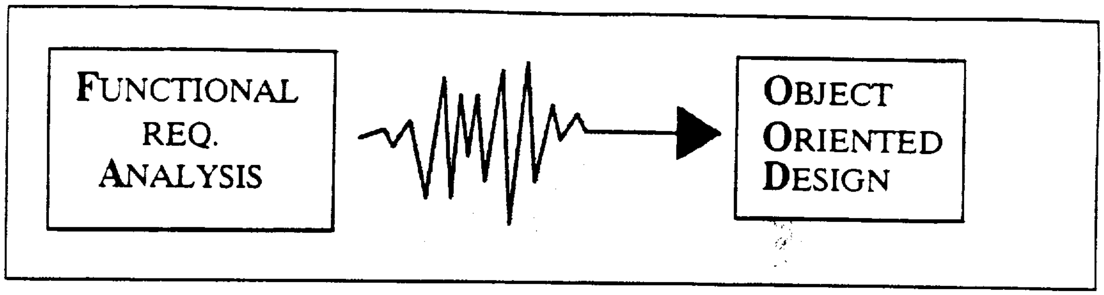


- CONSISTENCY OF METAPHOR

- POOR MAINTAINABILITY
- LIMITED REUSE POTENTIAL
- LEADS TO LIMITED USE OF ADA FEATURES

Object-Oriented Analysis -- Why?

TRADITIONAL TECHNIQUE | NOISE | DESIGN METHOD OF CHOICE

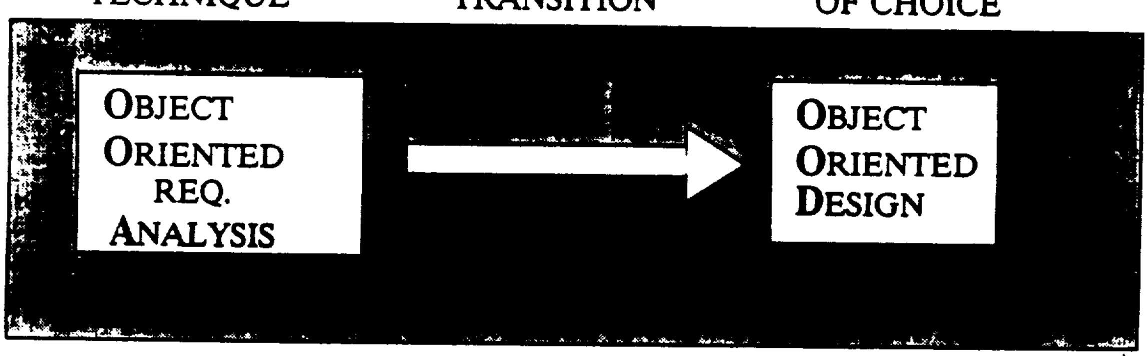


- LACK OF TRACABILITY
- LACK OF CONTINUITY BECAUSE OF SHIFT IN METAPHORS
- REQUIREMENTS OFTEN TAINTED WITH DESIGN

- MAPS TO REAL WORLD
- REUSE
- MAINTAINABILITY
- MAPS WELL TO ADA

Object-Oriented Analysis -- Why?

NEW TECHNIQUE | SMOOTH TRANSITION | DESIGN METHOD OF CHOICE



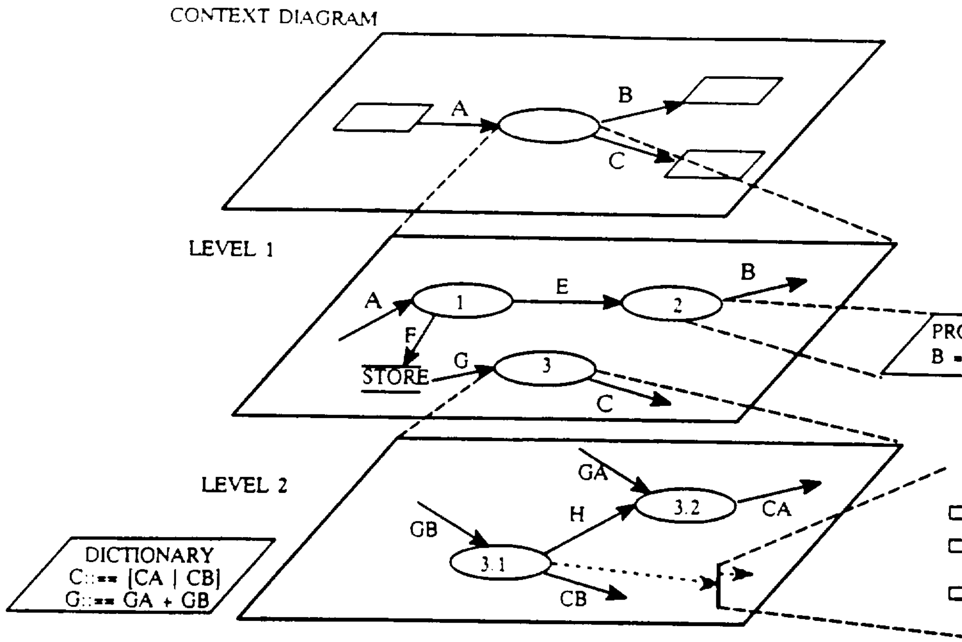
- MODELS REAL WORLD
- ALSO DESCRIBES FUNCTIONALITY
- POSSIBLE REUSE OF ANALYSIS
- MAINTAINABILITY

- TRACABILITY
- CONTINUITY OF METAPHORS
- REQUIREMENTS STILL TAINTED WITH DESIGN (BUT IMPACT IS MINI-MIZED)

- MAPS TO REAL WORLD
- REUSE
- MAINTAINABILITY
- MAPS WELL TO ADA

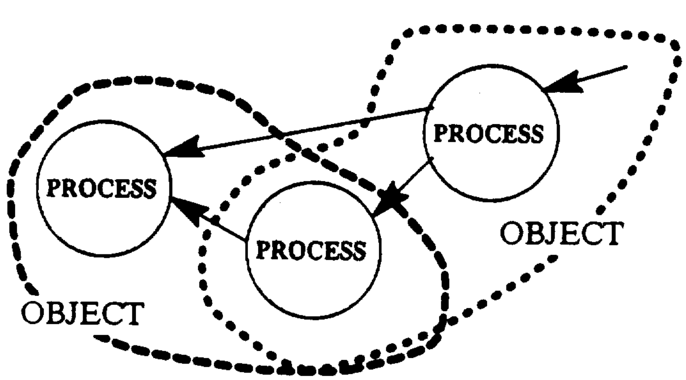
Traditional Case Tool

DATA FLOW + CONTROL FLOW + STATE TRANSISTION + PROCESS SPEC + DICTIONARY



Our First Attempt

STRUCTURED ANALYSIS WITH REAL-TIME EXTENSIONS + OBJECT CARVING = UNSUCCESSFUL



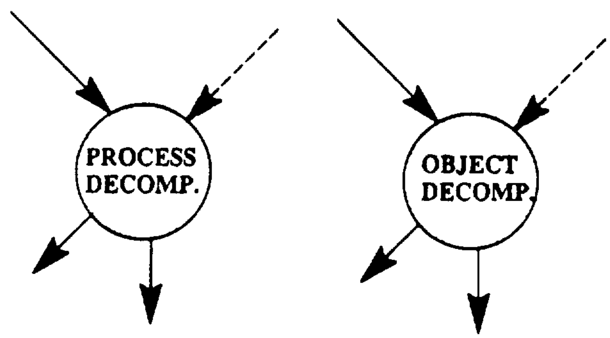
WEAKNESSES:

- MUST MAINTAIN TWO INDEPENDENT VIEWS
  - -- CREATED ANOTHER DIAGRAM TO MERGE VIEWS (MANUAL PROCESS)
- POTENTIAL FOR CONVOLUTED MAPPING BETWEEN OBJECTS AND FUNCTIONS

Our Second Attempt

PARALLEL DECOMPOSITION

OBJECT VIEW + FUNCTIONAL VIEW = UNSUCCESSFUL



STRENGTHS:

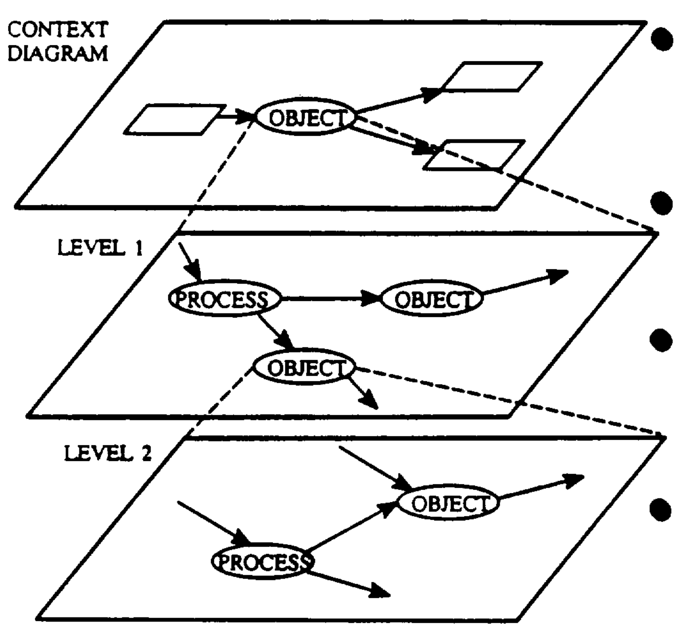
- SHOWS OBJECT INTERFACES

WEAKNESSES:

- MUST MAINTAIN TWO INDEPENDENT VIEWS
- CANNOT VERIFY EQUIVALENCE USING TOOL

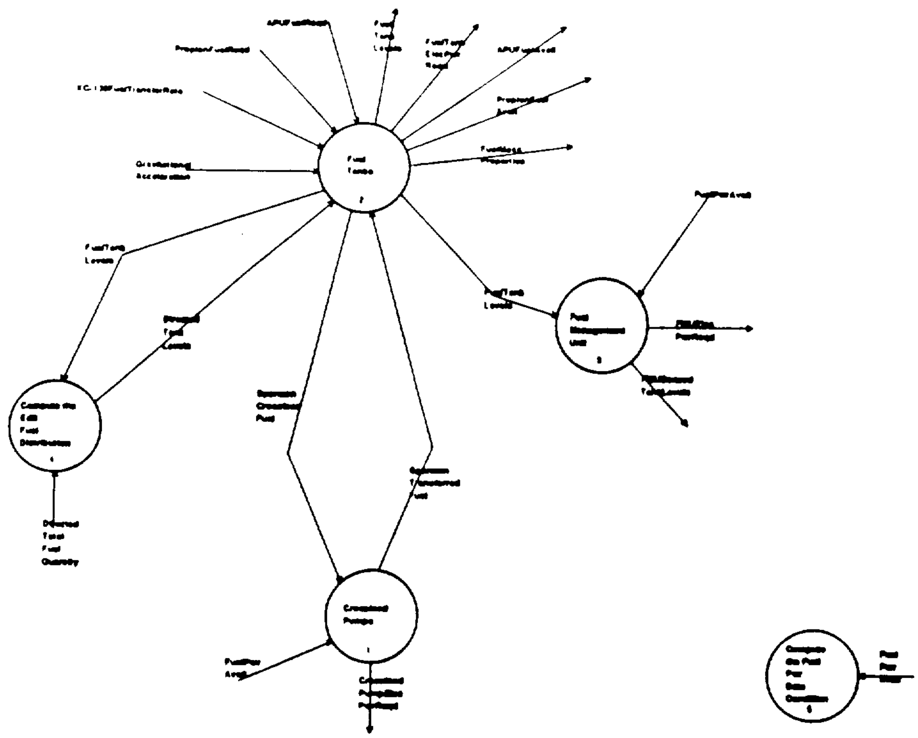
Our Third Attempt

FOD - FUNCTION/OBJECT DECOMPOSITION

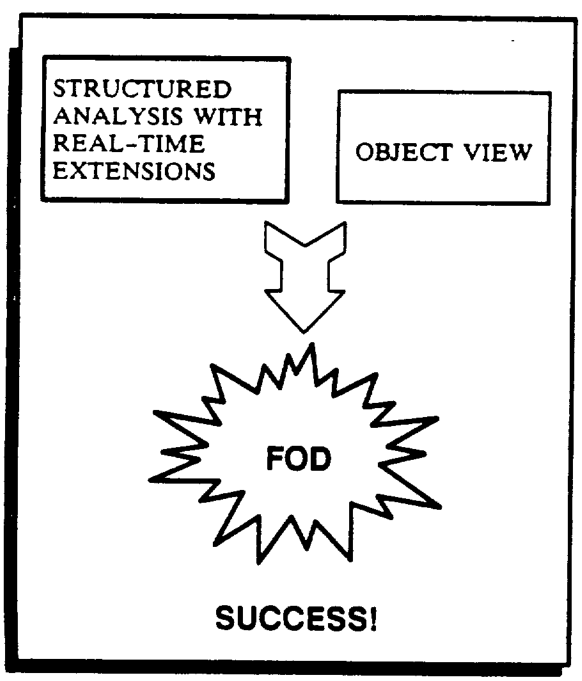


- SYNTHESIS OF
  - STRUCTURED ANALYSIS WITH REAL-TIME EXTENSIONS
  - OBJECTS
- BUBBLES CAN REPRESENT
  - FUNCTIONS
  - OBJECTS
- OBJECT CAN DECOMPOSE INTO
  - OTHER OBJECTS
  - FUNCTIONS OF PARENT OBJECT
- ONE SET OF DIAGRAMS HAS
  - OBJECT PARTITIONING
  - FUNCTIONS

Example of the FOD -- Decomposition of Fuel System

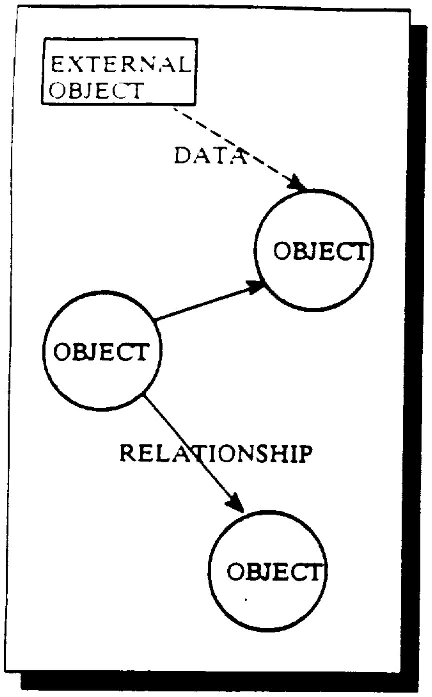


Observations on the FOD



- STRENGTHS
  - WE GOT SOMEWHERE!
  - FELT VERY NATURAL
  - GOOD FOR IDENTIFYING OBJECTS
  - ENSURES CONSISTENCY OF INTERFACES
- WEAKNESSES
  - EMPHASIS ON DATA DRIVES ANALYSIS INTO TOO MUCH DESIGN
  - REQUIREMENTS ARE NOT EXPLICIT -- MUST BE IMPLIED FROM DATA
  - DID NOT CREATE GOOD MIND-SET FOR OBJECT-ORIENTED DESIGN -- TENDED TO LEAD TO "INPUT-OUTPUT" DESIGNS

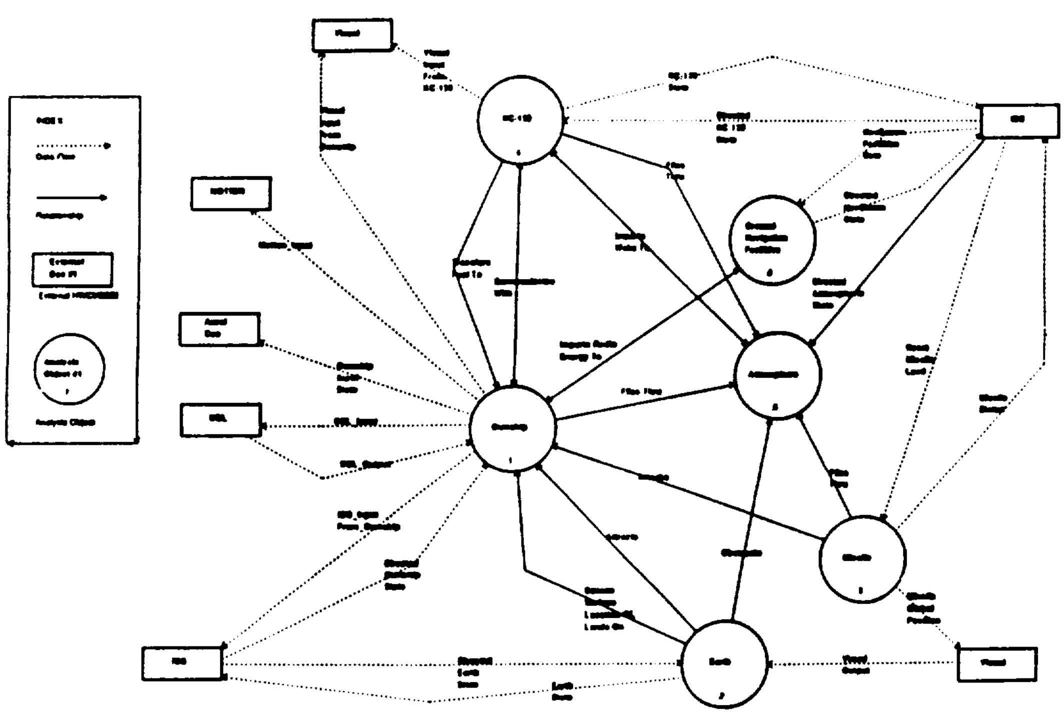
Our Latest Attempt -- Entity/Relationship-Based



- NOT TRADITIONAL ERDs
- BUBBLES REPRESENT OBJECTS
- FORMER "DATA FLOWS" ARE
  - DATA
    IF EXPLICITLY DEFINED BY REQUIREMENTS
    - MOST EXTERNAL OBJECTS
    - MAYBE OTHERS
  - RELATIONSHIPS
    IF DATA IS NOT DEFINED BY REQUIREMENTS
    - MOST DEVELOPED OBJECTS

Attempts at Object-Oriented Analysis
Using Traditional Case Tools

Example of ER Approach – A High Level View

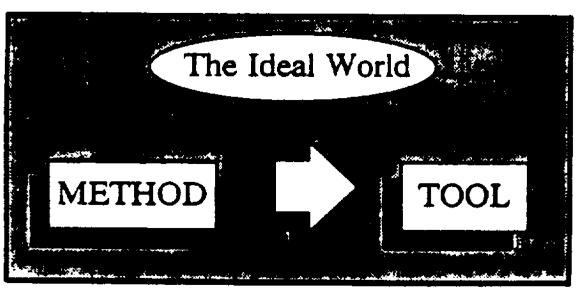


Observations on Our E/R Analysis

- WE USED E/R ANALYSIS FOR A SMALL PART OF PROJECT
- STRENGTHS
  - Good at identifying implementable objects
  - Keeps effort at the analysis level -- much less design is introduced
  - Good media for communication
  - Easily supports object oriented design. Relationships can easily be translated into data/operations during design
- WEAKNESSES
  - Some parts of tracability sacrificed
  - Layering/decomposition difficult -- tends to create layers of communicating objects

Attempts at Object-Oriented Analysis
Using Traditional Case Tools

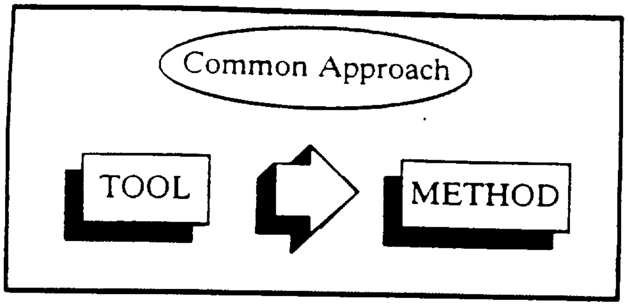
Interactions of Tools and Methods



- USES TRADITIONAL ENGINEERING APPROACH
- METHOD SELECTED BASED ON REQUIREMENTS
- TOOL SELECTED THAT SUPPORTS METHOD CHOSEN

- THE "IDEAL" WORLD RARELY EXISTS
  - MAY NOT BE TOOL TO SUPPORT DESIRED METHOD
  - NOT MANY PEOPLE CAN AFFORD TO BUILD CUSTOM TOOLS ANYMORE
  - TOOLS MAY BE DICTATED BY THE CUSTOMER
  - TOOL SELECTION MAY BE LIMITED BY AVAILABLE $$$$$$$
  - MAY BE REQUIRED TO USE EXISTING TOOLS AND/OR PLATFORMS

Interactions of Tools and Methods

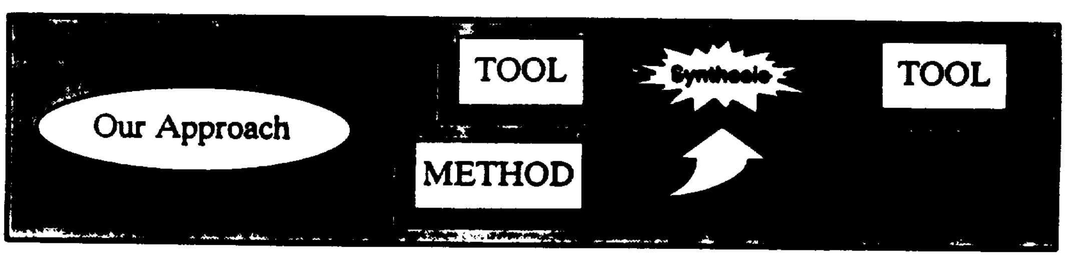


- TOOL BECOMES BASIS FOR ENGINEERING PROCESS
- USES METHOD EXPLICITLY SUPPORTED BY THE TOOL

- **THIS APPROACH MAY NOT BE EFFECTIVE:**
  - THE "DEFACTO" METHOD MAY NOT PRODUCE THE DESIRED RESULTS
  - SET OF POSSIBLE METHODS ARE LIMITED BY SET OF POSSIBLE TOOLS
    - SIGNIFICANT LAG TIME BETWEEN IMPROVED METHODS AND TOOLS TO SUPPORT THEM
  - METHODS MAY BE DICTATED BY THE CUSTOMER
  - THE METHOD IMPLIED BY A TOOL USED IN ONE PHASE OF DEVELOPMENT MAY CONFLICT WITH THE METHOD OF DIFFERENT TOOLS USED IN OTHER PHASES

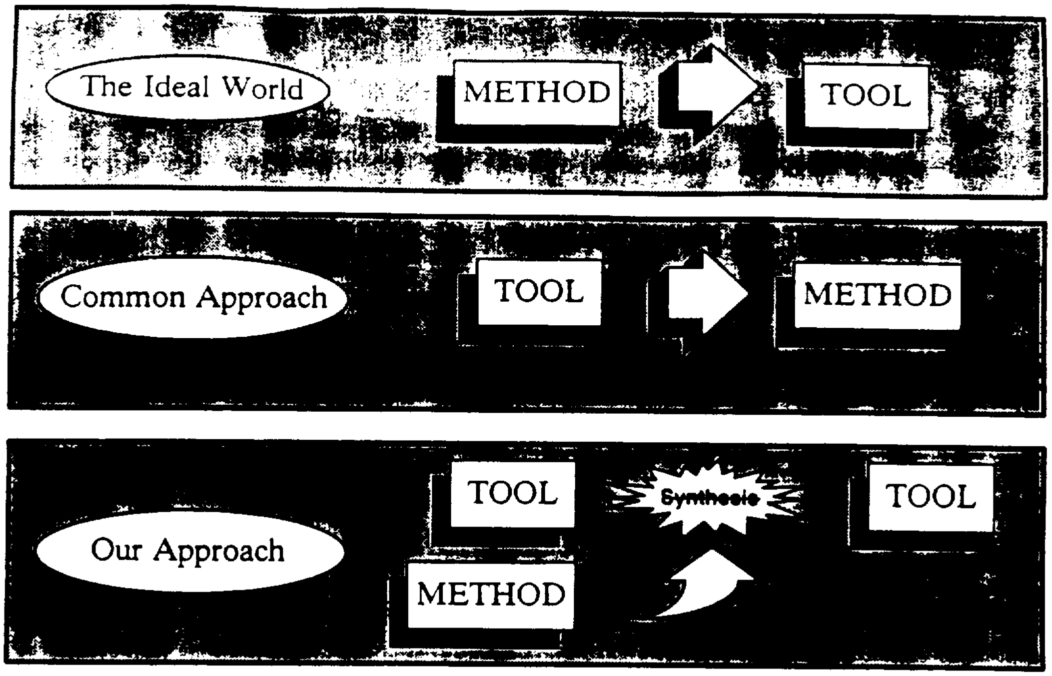
Attempts at Object-Oriented Analysis Using Traditional Case Tools

Interactions of Tools and Methods



- **SYNTHESIZES CAPABILITIES OF THE TOOL WITH METHOD**
  - NOT A PERFECT SOLUTION, BUT WORKS WITHIN LIMITATIONS OF TODAY'S TOOLS
  - WILL NOT BE REQUIRED AS METHODS STABILIZE AND TOOLS ARE BUILT TO SUPPORT THEM

Interactions of Tools and Methods



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MODELING AND ANALYSIS OF AEROSPACE SYSTEM COMPONENTS USING EASY5
(ENGINEERING ANALYSIS SYSTEM 5)

SABBIR A. HOSSAIN, PhD
November 07, 1989

- INTRODUCTION
- SPACECRAFT / SPACE SHUTTLE SYSTEM COMPLEXITY
- DIFFICULT TO DESIGN, TEST AND TROUBLE-SHOOT LARGE SCALE SYSTEM
- NEED FOR MORE POWERFUL TECHNIQUES FOR MODELING AND ANALYSIS OF A SYSTEM BEFORE THEY ARE BUILT
- FOR ELECTRICAL CIRCUITS/SYSTEMS - SPICE
- FOR DYNAMIC SYSTEM - DEDICATED MODEL OF SPECIFIC SYSTEMS

- COMMON DRAWBACK:
  WITH INCREASED COMPONENTS/COMPLEXITY
  INCREASED MEMORY REQUIREMENTS
  INCREASED CPU TIME
  CONVERGENCE PROBLEMS
  LACK OF FLEXIBILITY FOR FUTURE MODIFICATION
- MODULAR APPROACH TO MODEL BUILDING WITH FOLLOWING ATTRIBUTES:
  - ACCURACY TO PROVIDE SUFFICIENT DETAILS ABOUT THE BEHAVIOR OF THE INDIVIDUAL COMPONENTS FOR DESIGN AND TROUBLESHOOTING
  - VERIFIABLE WHENEVER EQUIPMENT OR SUBSYSTEM EXPERIMENTAL TESTING IS POSSIBLE
  - FLEXIBLITY FOR FUTURE MODIFICATION
  - EFFICIENCY FOR COMPUTER CORE MEMORY AND COMPUTATIONAL TIME
- MODULAR APPROACH - EASY5, MATRIX X, CONTROL C
  EXPERIENCED WITH EASY5

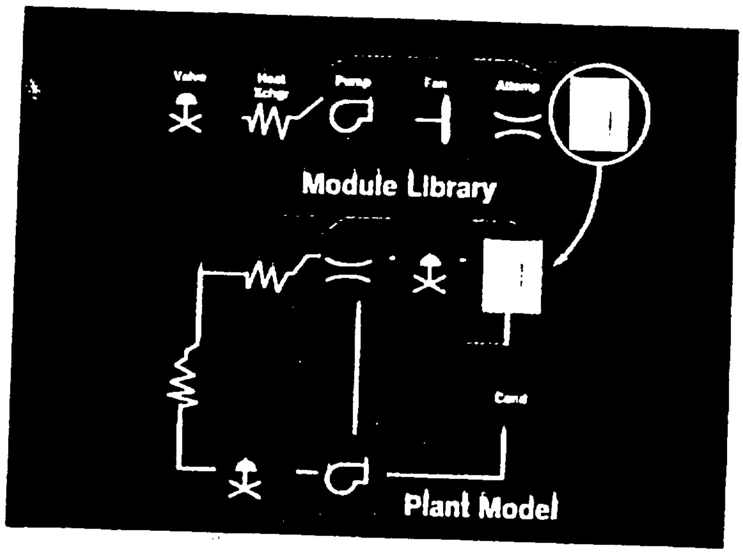
• FEATURES:

• EASY5/W ALLOWS ONE TO MODEL A DYNAMIC SYSTEM USING PREDEFINED MODEL COMPONENTS CONTAINED IN EASY5 LIBRARIES OR CUSTOM DEFINED LIBRARIES.

• MODEL AND ANALYZE BOTH CONTINUOUS AND DISCONTINUOUS, LINEAR AND NONLINEAR, AND MULTI-RATE SAMPLED DATA SYSTEMS.

• USE ONE SYSTEM MODEL FOR BOTH LINEAR AND NONLINEAR ANALYSIS.

• MODELING PROGRAM CAN BE FORTRAN, ADA, PASCAL OR C.



• EASY5/W PERMITS ONE TO:

• SIMULATE DYNAMIC BEHAVIOR OF A NONLINEAR OR LINEAR SYSTEM.

• LOCATE A STEADY-STATE OPERATING POINT FOR A NONLINEAR MODEL.

• PERFORM THE FOLLOWING LINEAR ANALYSES:

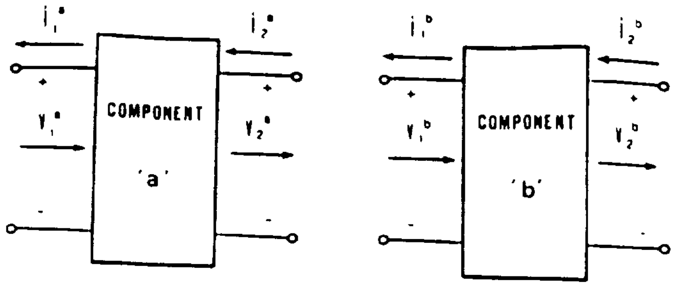
FREQUENCY RESPONSE
ROOT LOCUS
EIGENVALUE SENSITIVITY
POWER SPECTRAL DENSITY
TRANSFER FUNCTION
LINEAR MODEL GENERATION
SINGULAR VALUES
STABILITY MARGINS

• DISPLAY AND PRINT FOLLOWING ANALYSIS RESULTS:

BODE PLOTS
NYQUEST PLOTS
ROOT LOCUS PLOTS
NICHOLS PLOTS
PHASE PLANE PLOTS

• PERFORM CONTROL SYSTEM DESIGN WITH:

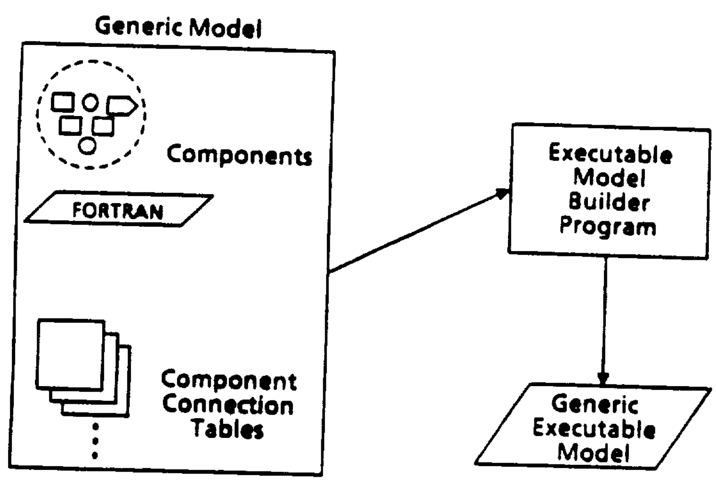
PARAMETER OPTIMIZATION
OPTIMAL CONTROLLER DESIGN

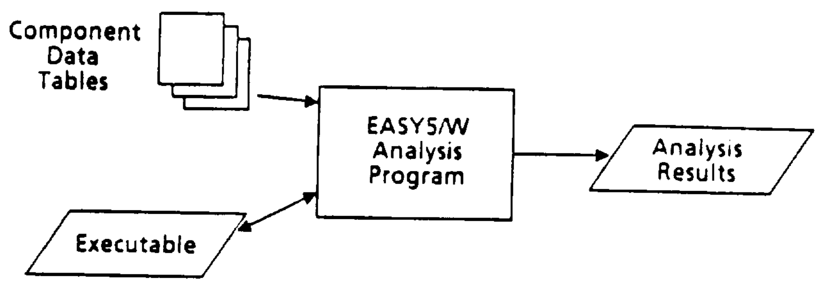


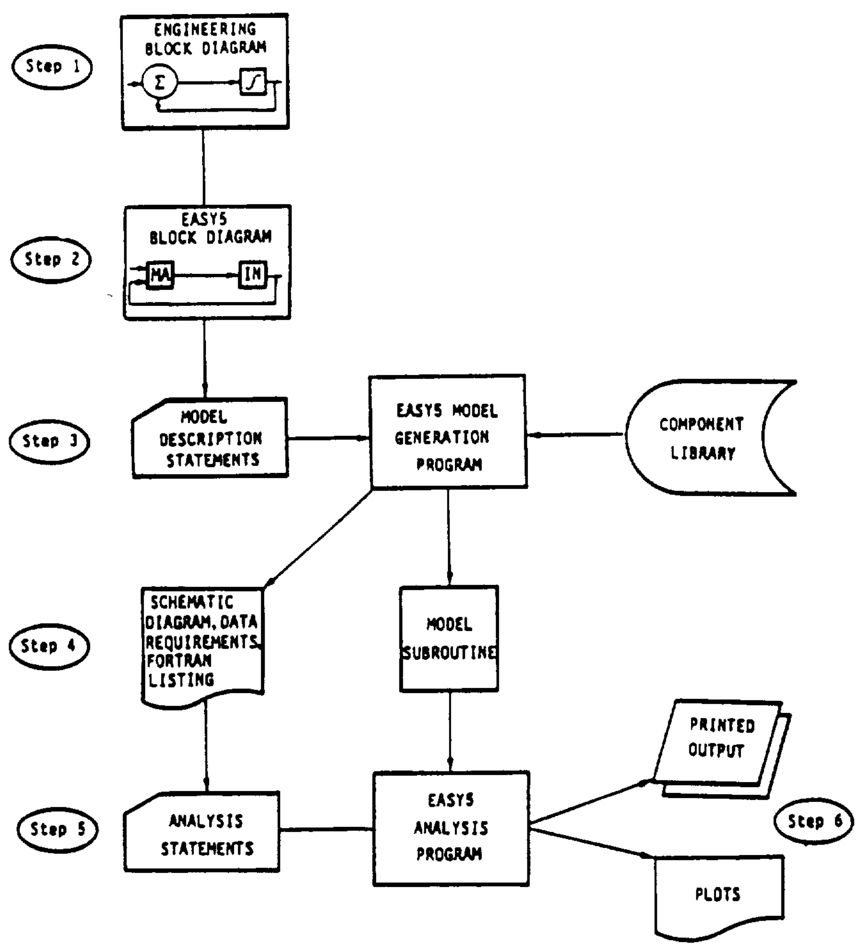
Two-port component coupling.

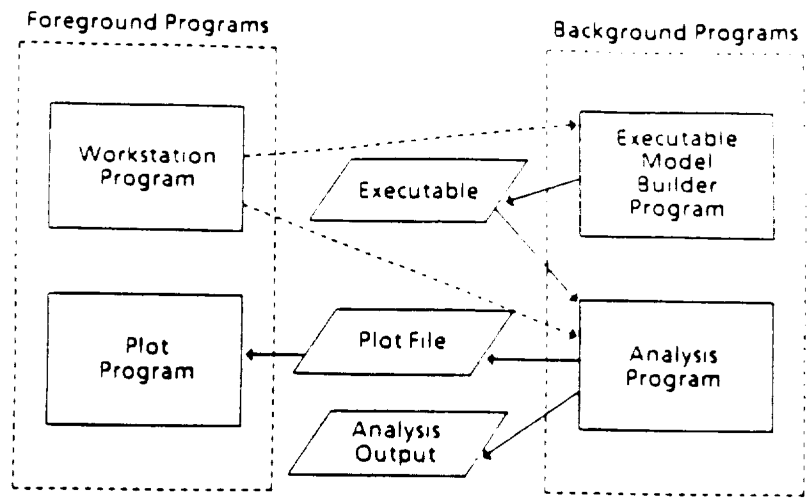
The terminal characteristics of each component are described by the following equation:

$$\begin{bmatrix} i_1 \\ v_2 \end{bmatrix} = \begin{bmatrix} h_{11} & h_{12} \\ h_{21} & h_{22} \end{bmatrix} \begin{bmatrix} v_1 \\ i_2 \end{bmatrix}. \qquad (1)$$



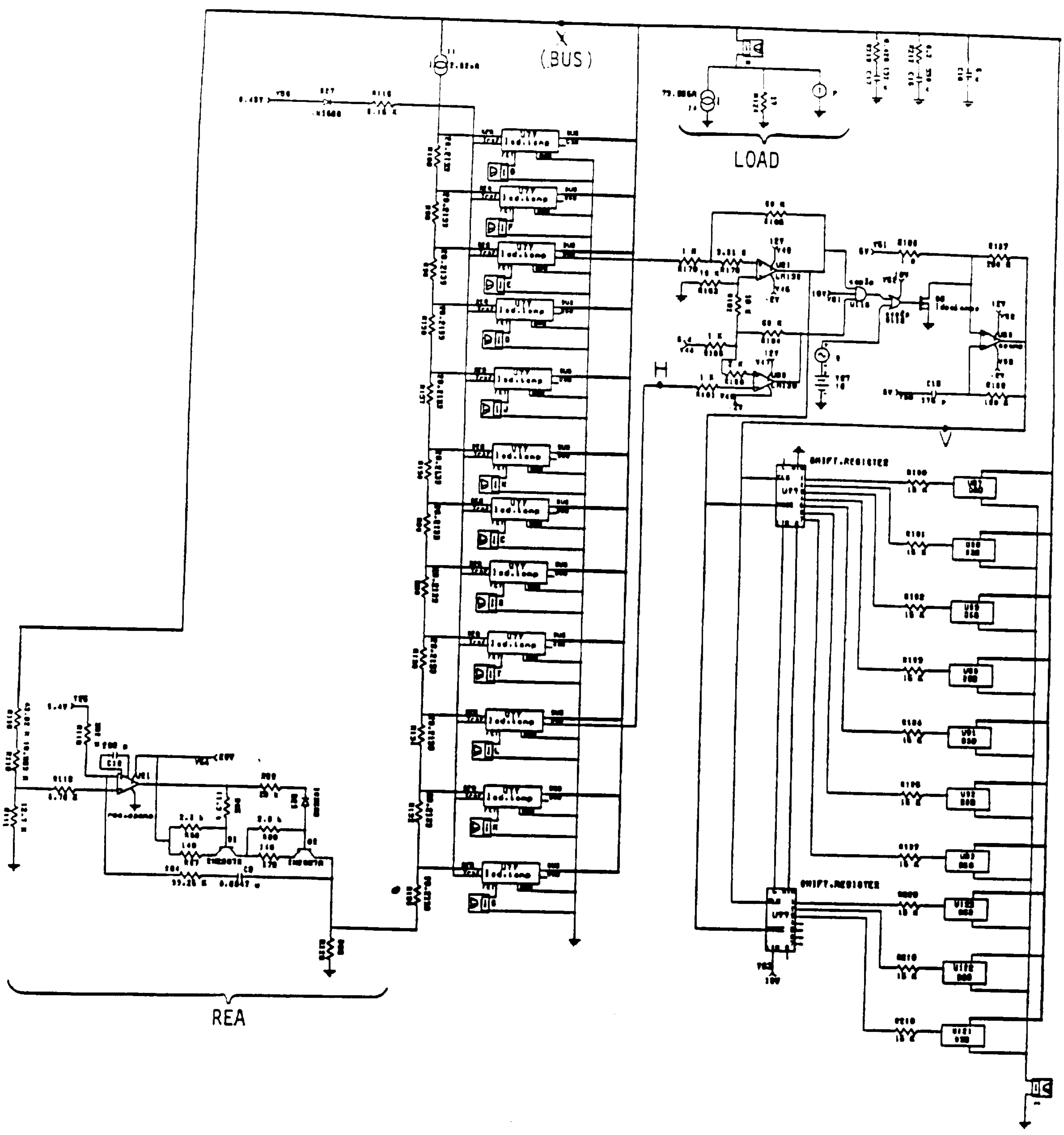

Component
Data
Tables
EASY5/W
Analysis
Program
Analysis
Results
Executable


Step 1
ENGINEERING
BLOCK DIAGRAM
Step 2
EASY5
BLOCK DIAGRAM
MA
IN
Step 3
MODEL
DESCRIPTION
STATEMENTS
EASY5 MODEL
GENERATION
PROGRAM
COMPONENT
LIBRARY
Step 4
SCHEMATIC
DIAGRAM, DATA
REQUIREMENTS,
FORTRAN
LISTING
MODEL
SUBROUTINE
PRINTED
OUTPUT
Step 5
ANALYSIS
STATEMENTS
EASY5
ANALYSIS
PROGRAM
Step 6
PLOTS

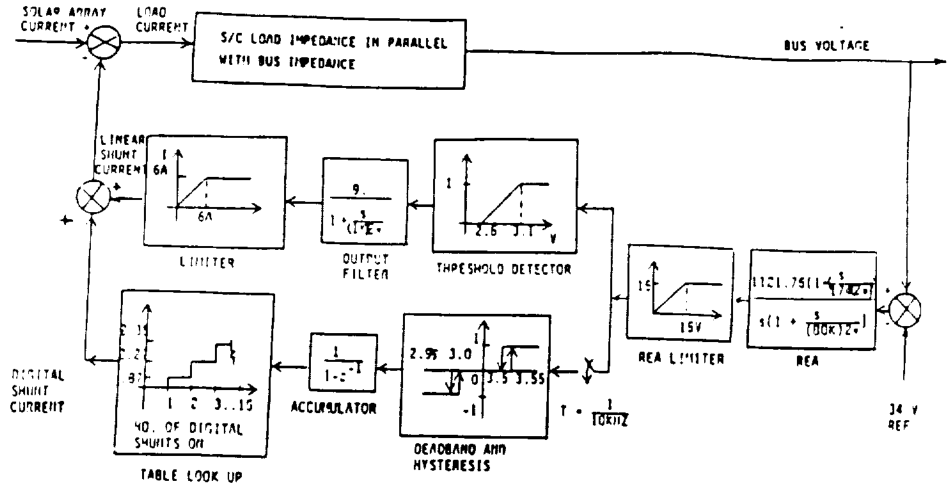


EASY5/W PROGRAM STRUCTURE

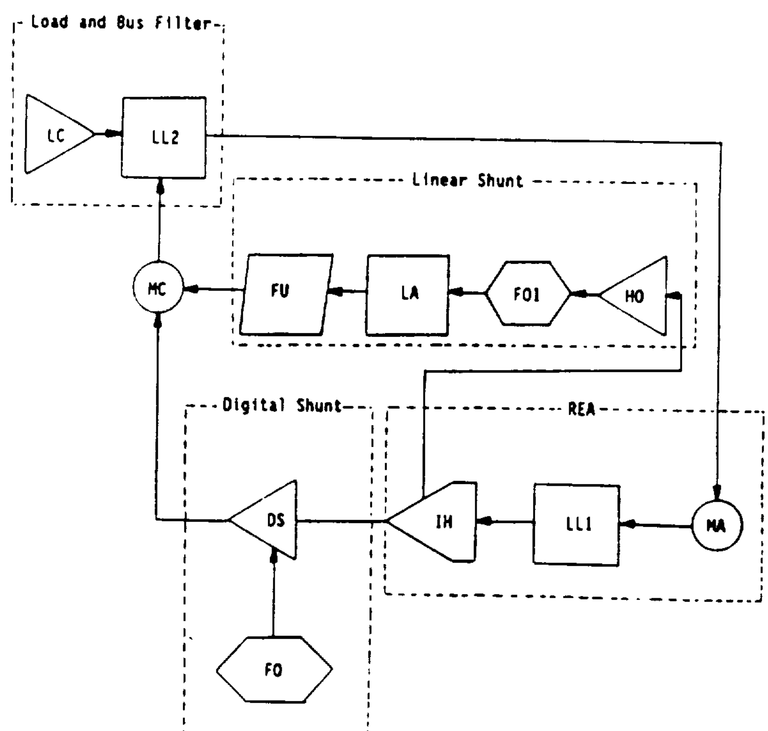
- TWO EXAMPLES OF APPLICATION OF EASY5 IN SPACECRAFT HARDWARE SIMULATION AND TRUBLESHOOTING
    - SHUNT CONTROL VOLTAGE REGULATOR FOR SPACE SATELLITE
    - AUXILIARY POWER UNIT (APU)



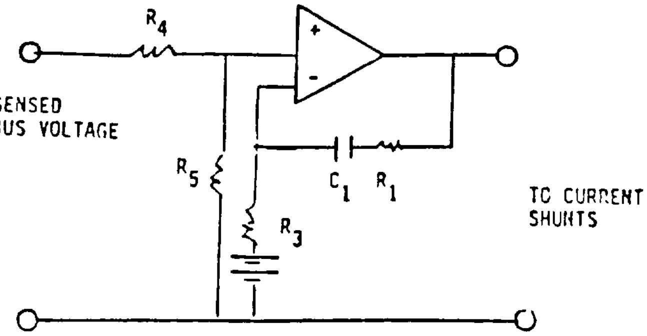
SHUNT CONTROL BUS VOLTAGE REGULATOR



MATHEMATICAL MODEL OF THE VOLTAGE REGULATOR



EASY5 MODEL OF SHUNT CONTROL VOLTAGE REGULATOR



$$G_{REA}(s) = \frac{R_5}{R_3 C_1 (R_4 + R_5)} \left\{ \frac{1 + (R_1 + R_3) C_1 s}{s} \right\}$$

R_1 = 16200. Ω

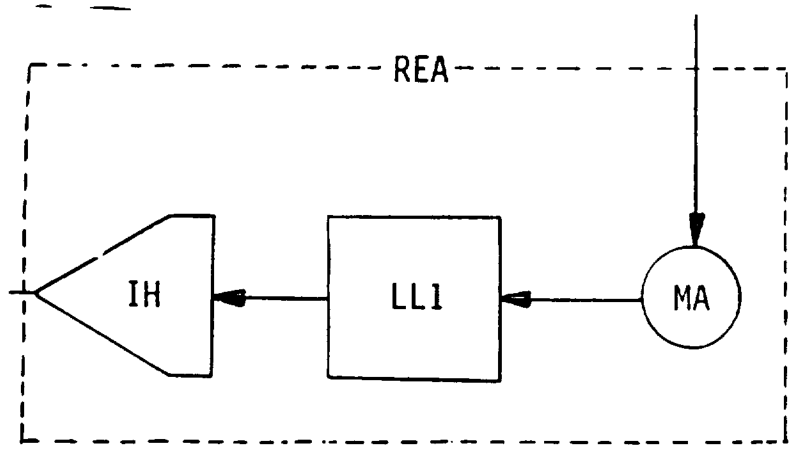
R_3 = 3166. Ω

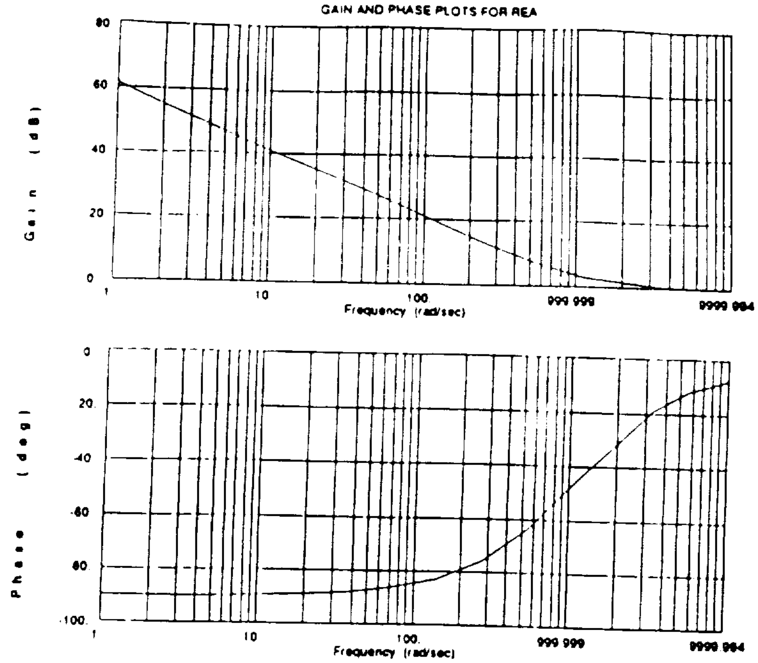
R_4 = 27400. Ω

R_5 = 5490. Ω

C_1 = .047 μf

Regulator error amplifier model.





The gain and phase curves for the REA.

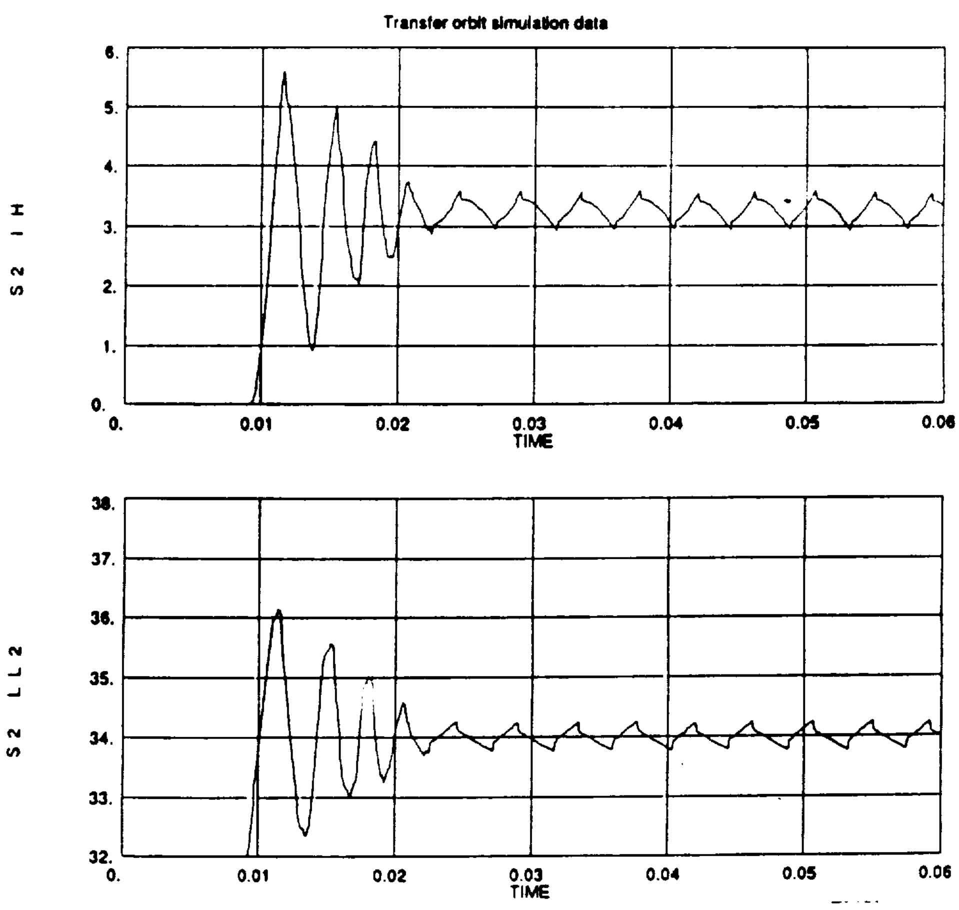


Fig. 11 Step responses for the single shunt model with Gain = 18 and Delay = 1 mS for :
(a) REA output voltage
(b) Bus voltage.

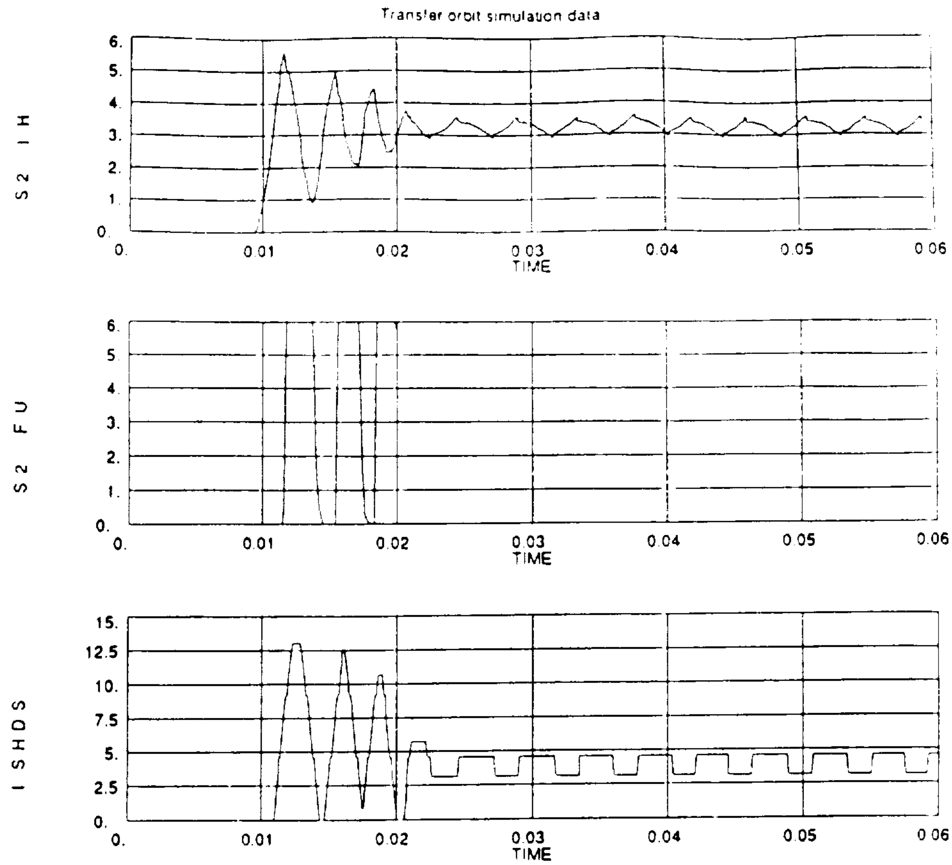


Fig. 11 Contd.
(c) REA output voltage
(d) Linear shunt output
(e) Digital shunt output.

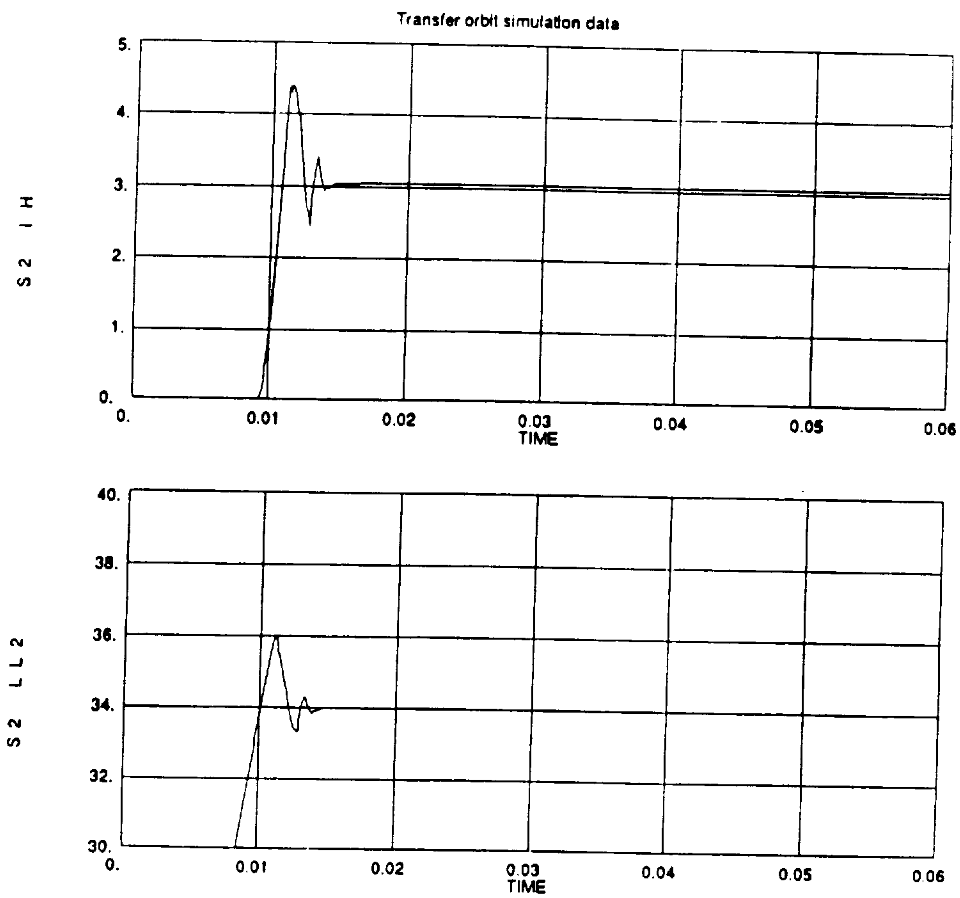


Fig. 15 Step responses for the single shunt model with Gain = 12.0 and Delay = .5 mS for :
(a) REA output voltage

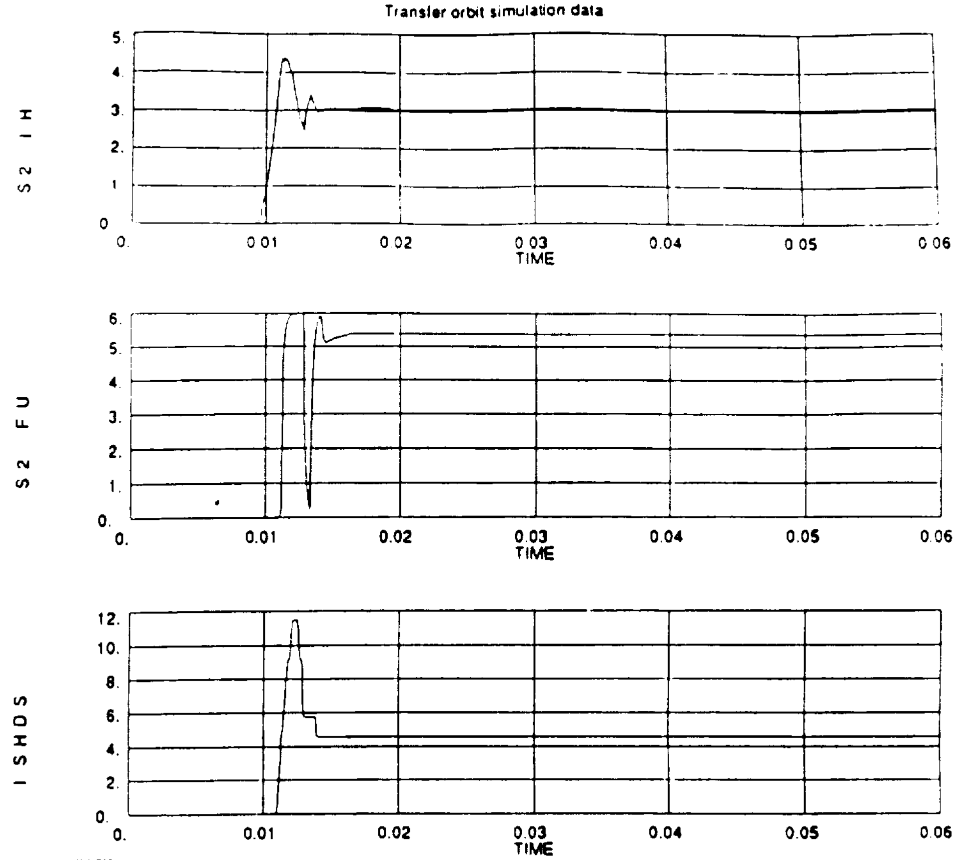
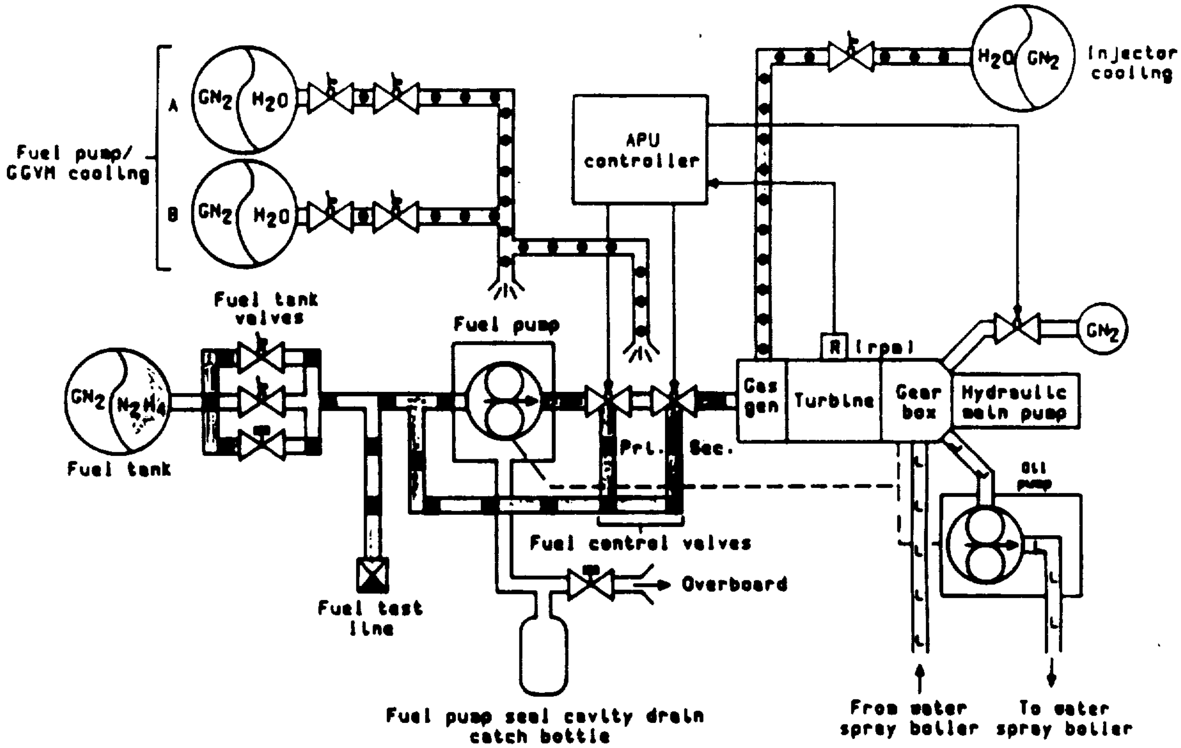
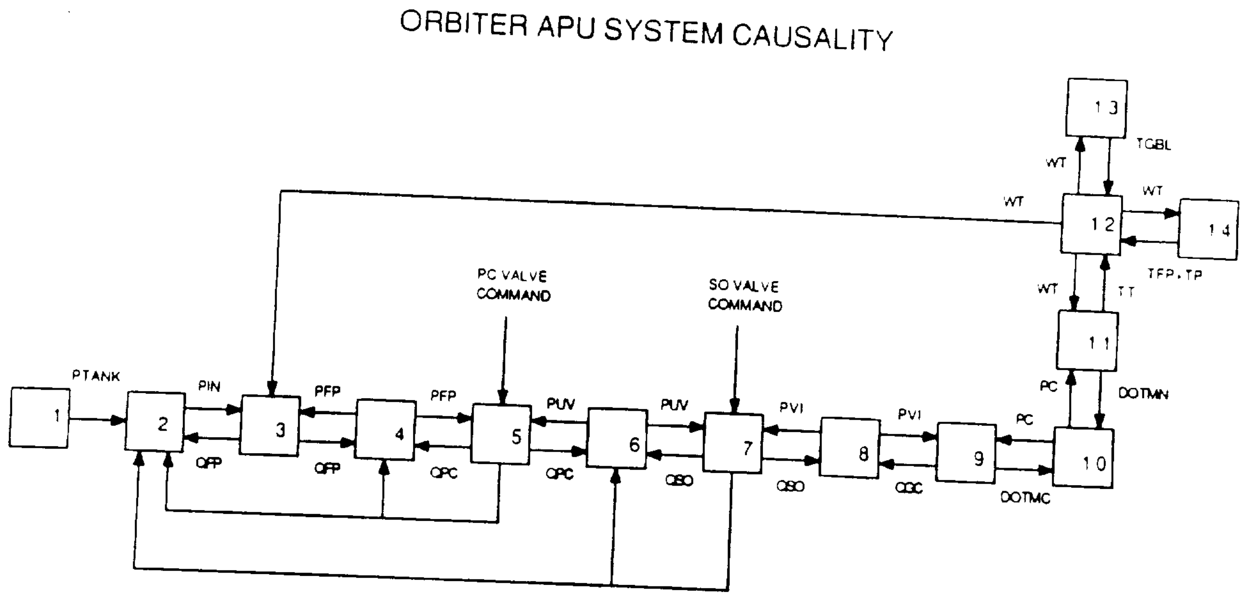


Fig. 15 Contd.
(c) REA output voltage
(d) Linear shunt output
(e) Digital shunt output.



APU Subsystem Schematic



1. FUEL TANK
2. FUEL TANK TO FUEL PUMP FLUID INERTIA AND COMPRESSIBILITY
3. FUEL PUMP
4. FUEL PUMP TO PC VALVE FLUID COMPRESSIBILITY
5. PC VALVE
6. PC VALVE TO SO VALVE FLUID COMPRESSIBILITY
7. SO VALVE
8. SO VALVE TO INJECTOR COMPRESSIBILITY
9. INJECTOR
10. COMBUSTOR COMPRESSIBILITY
11. TURBINE
12. LUMPED SYSTEM INERTIA
13. GEARBOX LOAD
14. PUMP LOAD (FEED PUMP AND HYDRAULIC PUMP)

Figure 5: APU system causality.

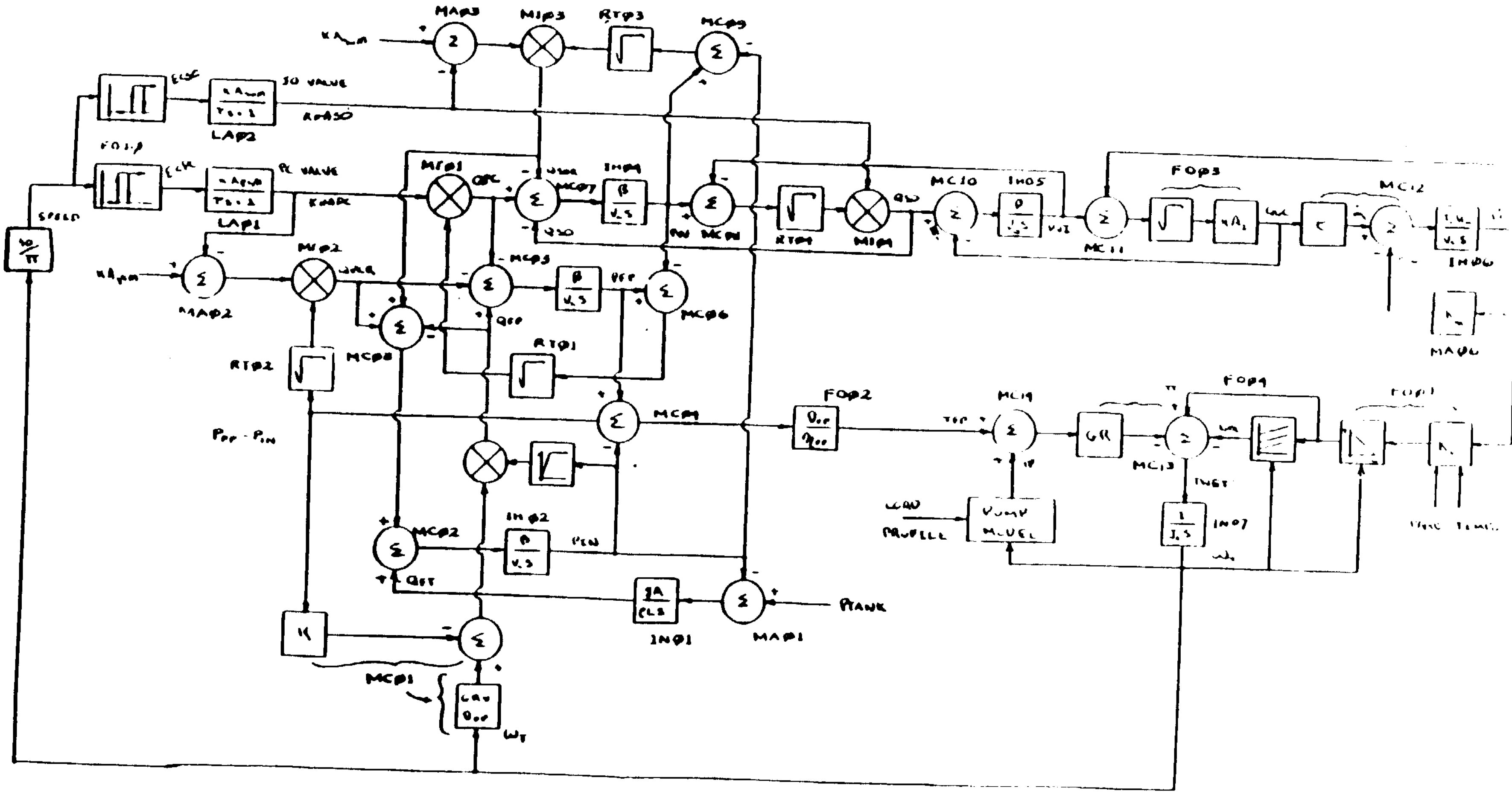


Figure 6: APU system model.

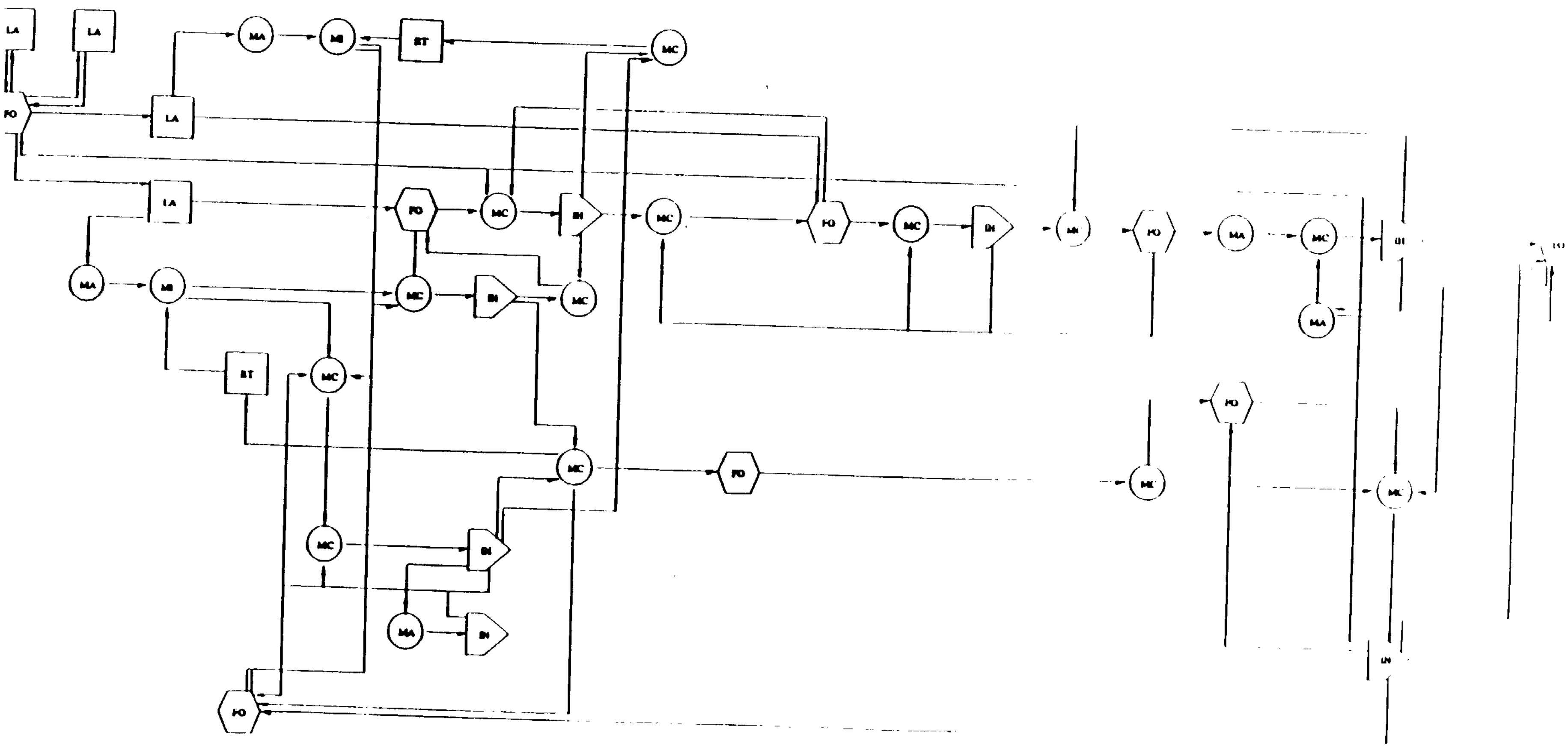
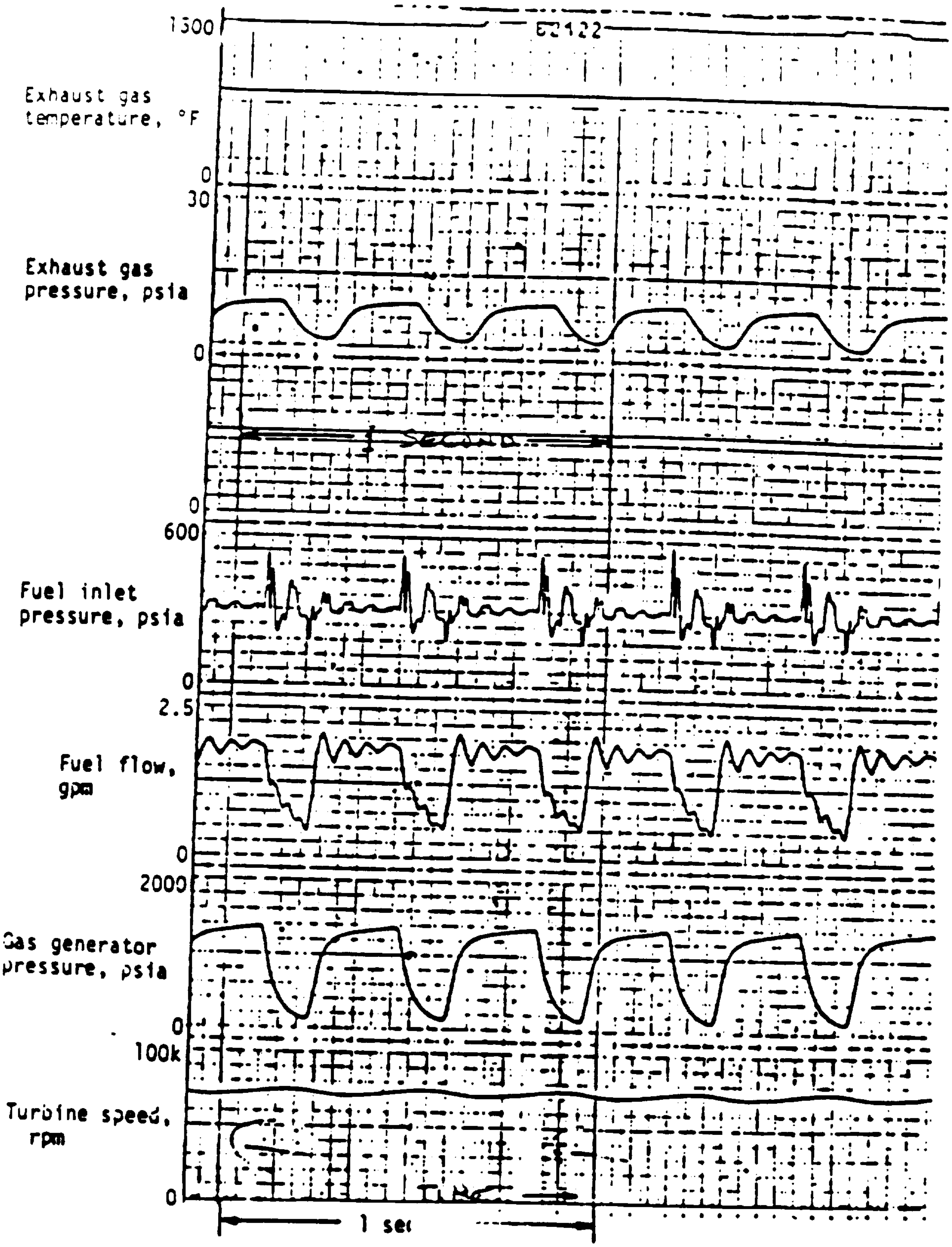
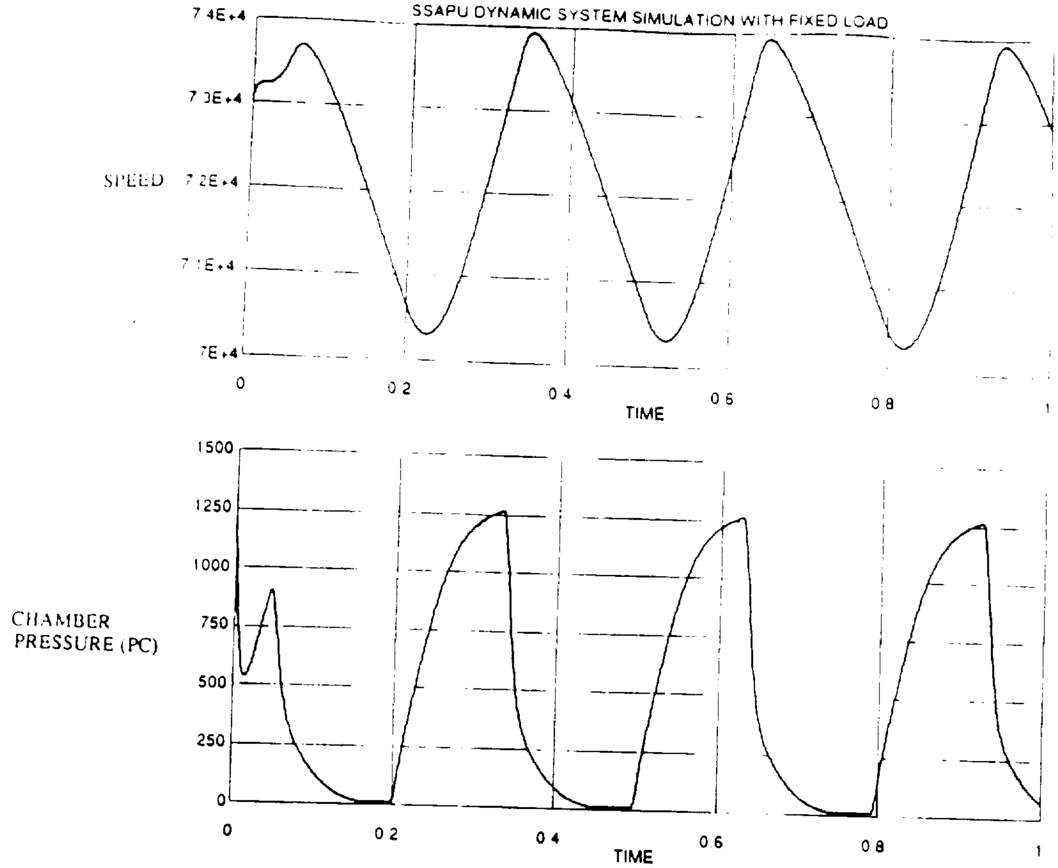


Figure 7: APU EASY5 equivalent model.

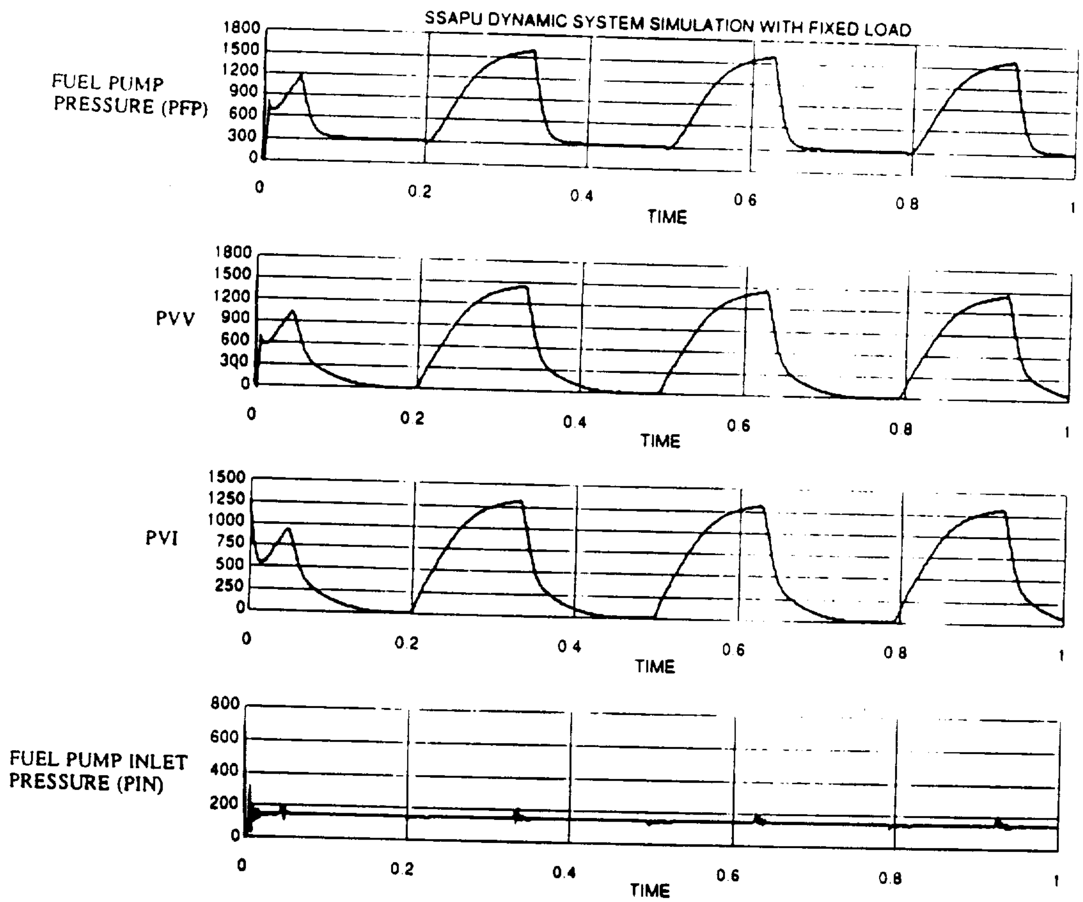


DATA SET 4

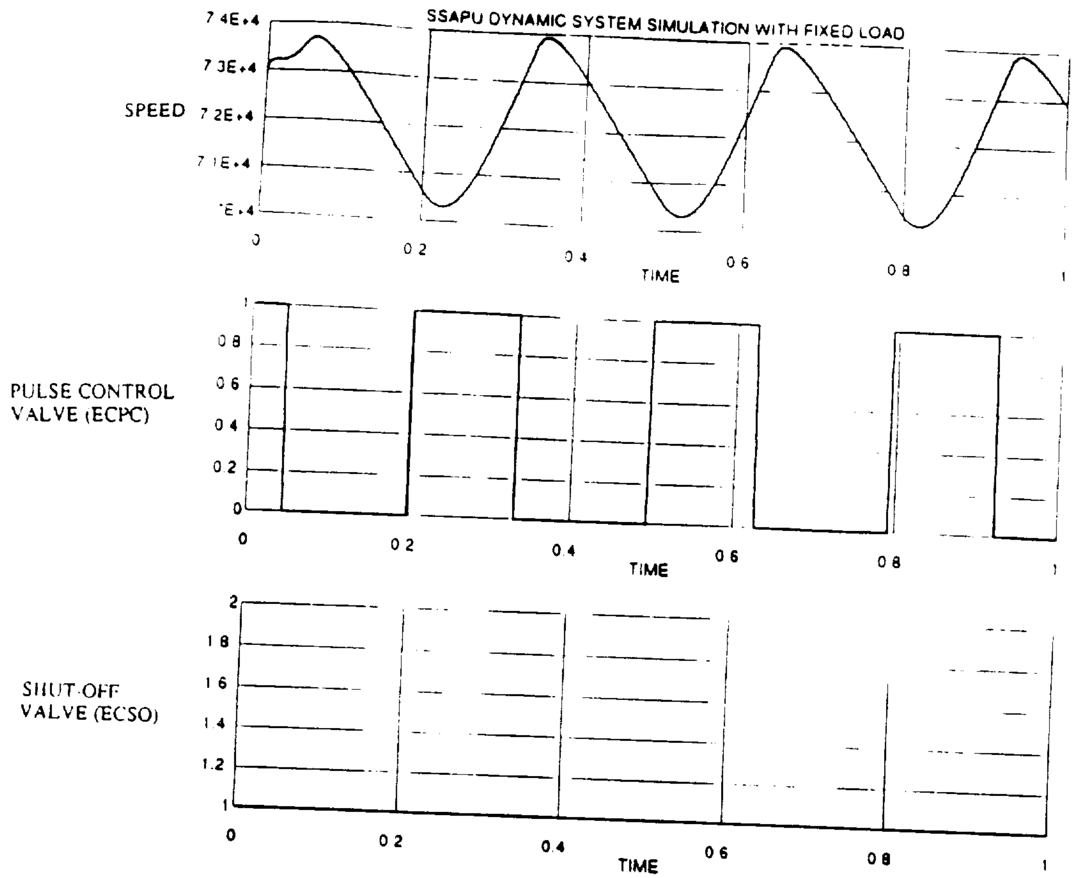
APU OPERATING CHARACTERISTICS IN SPACE (103
PERCENT SPEED 129 HP).



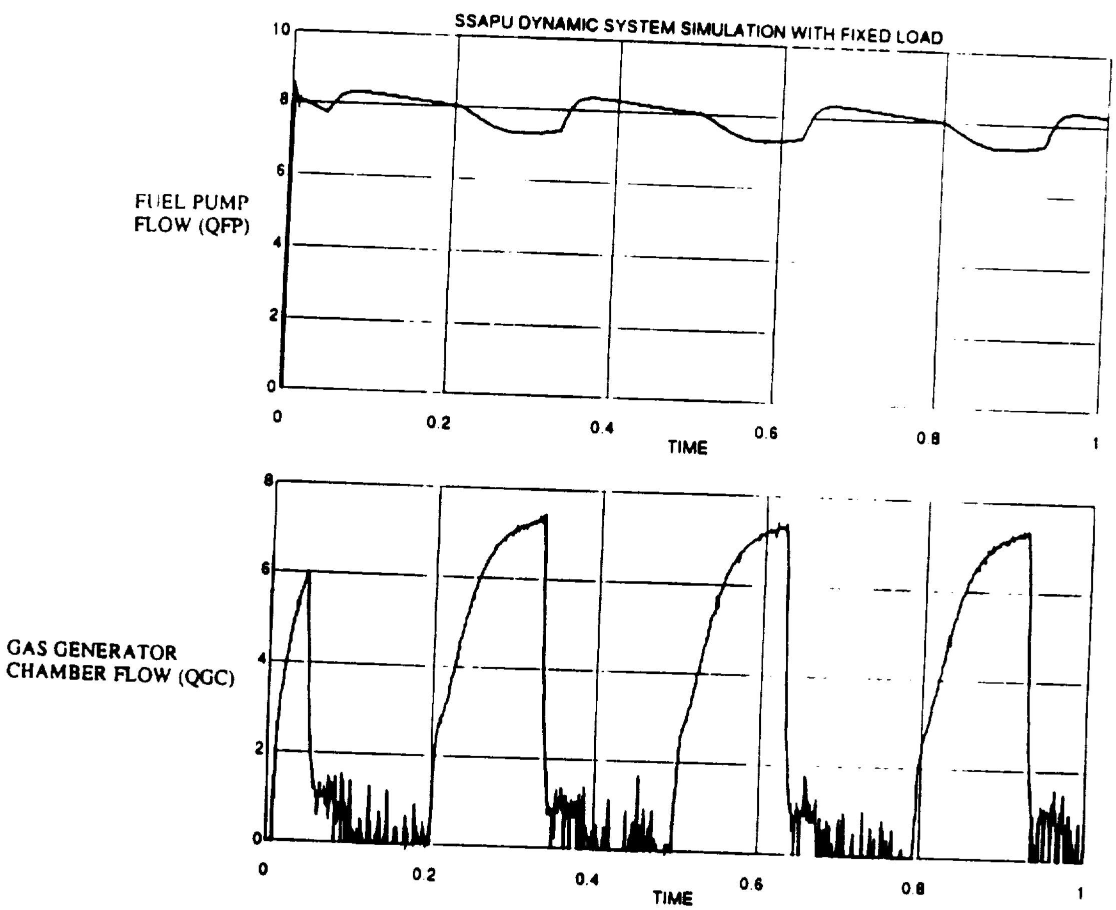
Display 1: Simulation



Display 2: Simulation



Display 5: Simulation



Display 7: Simulation

24-MAR-89 22:48

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MISSION OPERATIONS DIRECTORATE
TRAINING DIVISION

THE ROLE OF TRAINING REQUIREMENTS ANALYSIS IN DEFINING SIMULATION REQUIREMENTS FOR TRAINING

NOVEMBER 7, 1989

SUSAN TEMPLE

PURPOSE OF PRESENTATION

- PROVIDE AN OVERVIEW OF THE TRAINING REQUIREMENTS ANALYSIS PROCESS BEING USED FOR SPACE STATION FREEDOM
- DEMONSTRATE HOW TRAINING REQUIREMENTS ANALYSIS AIDS IN THE DEFINITION OF SIMULATION REQUIREMENTS FOR TRAINING

1

HISTORICAL PERSPECTIVE

SHUTTLE MISSION SIMULATOR (SMS) REQUIREMENTS DEFINITION:

- BASED ON PREVIOUS PROGRAMS
- TRAINING TASKS WERE EITHER NOT IDENTIFIED OR WERE NOT WELL UNDERSTOOD
- SUPPORTED HIGH FIDELITY SIMULATION OF THE VEHICLE
- TOO MANY DIFFERENT WAYS TO FAIL A "BLACK BOX"
- REQUIRED FIDELITY OF FAILURE SIGNATURES WAS LACKING

2

LESSONS LEARNED

- NOT ALL TASKS REQUIRE A HIGH FIDELITY SIMULATOR
- A WELL ORGANIZED CREW TRAINING CATALOG HAS EVOLVED OVER THE PAST 13 YEARS
- THE STS TRAINING PROGRAM IS SLOWLY EVOLVING TOWARD OBJECTIVES
- NEW "TRAINERS" ARE BEING DEVELOPED WHICH OFF-LOAD THE SMS

LESSONS LEARNED

- SMS FIDELITY HAS BEEN DECREASING IN SOME AREAS AND INCREASING IN OTHER AREAS AS TRAINING TASKS ARE MORE FULLY UNDERSTOOD
- WE LEARNED BY DOING

WHERE DO WE GO FROM HERE?

QUESTION: HOW DO WE IMPROVE OUR ABILITY TO IDENTIFY SIMULATION REQUIREMENTS FOR THE SPACE STATION FREEDOM?

ANSWER: PERFORM A TRAINING REQUIREMENTS ANALYSIS

SPACE STATION FREEDOM TRAINING REQUIREMENTS ANALYSIS

TASK ANALYSIS IS BEING CONDUCTED FOR:

- CREW
- GROUND SUPPORT PERSONNEL IN THE SPACE STATION CONTROL CENTER
- INSTRUCTORS

USING AUTOMATED TOOL TO CONDUCT THE TASK ANALYSIS

- REQUIREMENTS DEFINITION ANALYSIS SYSTEM (RDAS)

DEFINITION OF TRAINING REQUIREMENTS ANALYSIS

THE SYSTEMATIC PROCESS OF ANALYZING TASKS TO DETERMINE:

- THE COMPONENT TASKS OF A JOB
- THE TRAINING ACTIONS WHICH NEED TO BE DEVELOPED TO OBTAIN THE REQUIRED PERFORMANCE

PURPOSE OF TRAINING REQUIREMENTS ANALYSIS

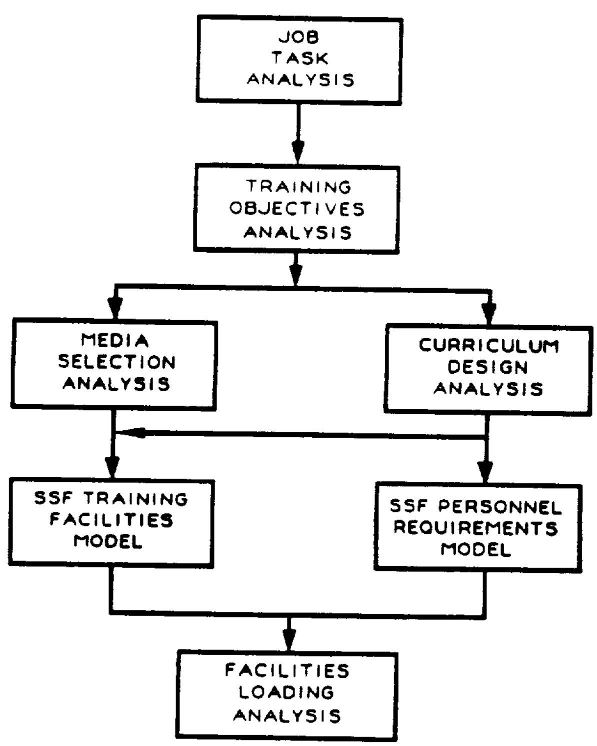
TO IDENTIFY THE:

- TASKS WHICH MUST BE PERFORMED
- SKILLS AND BEHAVIORS REQUIRED TO PERFORM THE TASKS
- CONDITIONS UNDER WHICH THE TASK MUST BE PERFORMED
- SKILL LEVEL/MASTERY LEVEL REQUIRED FOR ACCEPTABLE PERFORMANCE

BENEFITS OF TRAINING REQUIREMENTS ANALYSIS

- IDENTIFIES TRAINING REQUIREMENTS
- ESTABLISHES ADEQUATE JOB PERFORMANCE GUIDELINES
- IDENTIFIES OPTIMAL TRAINING STRATEGIES, METHODOLOGIES, AND MEDIA
- IDENTIFIES PROPER SEQUENCING OF TRAINING
- ELIMINATES UNNECESSARY TRAINING
- REDUCES TRAINING COSTS

SPACE STATION FREEDOM TRAINING REQUIREMENTS ANALYSIS



JOB TASK ANALYSIS

- IDENTIFIES CRITICAL TASKS, SKILLS, AND KNOWLEDGE REQUIREMENTS
- PRODUCT:

  TASK HIERARCHY DATABASE REPORT

TASK HIERARCHY LEVELS AND DEFINITIONS

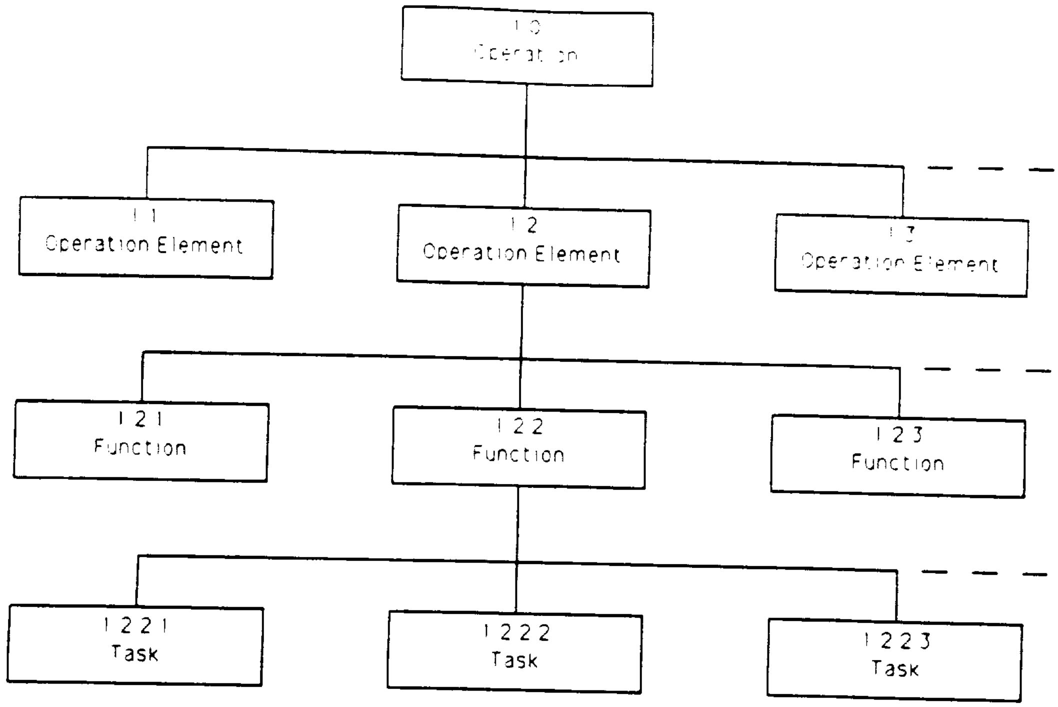
OPERATION: END GOAL OF COORDINATED ACTIVITY OF A SYSTEM OF INDIVIDUALS

OPERATION ELEMENT: TIME SLICE OF AN OPERATION WITH A LOGICAL BEGINNING AND END POINT

FUNCTION: LARGEST SEGMENT OF WORK WITHIN AN ELEMENT PERFORMED BY A SPECIFIC INDIVIDUAL OR IDENTIFIABLE TEAM

TASK: NECESSARY STEP IN PERFORMANCE WITH LOGICAL BEGINNING AND END. LOWEST LEVEL THAT PERFORMANCE CAN BE EVALUATED

GENERIC FLOW CHART OF TASK HIERARCHY



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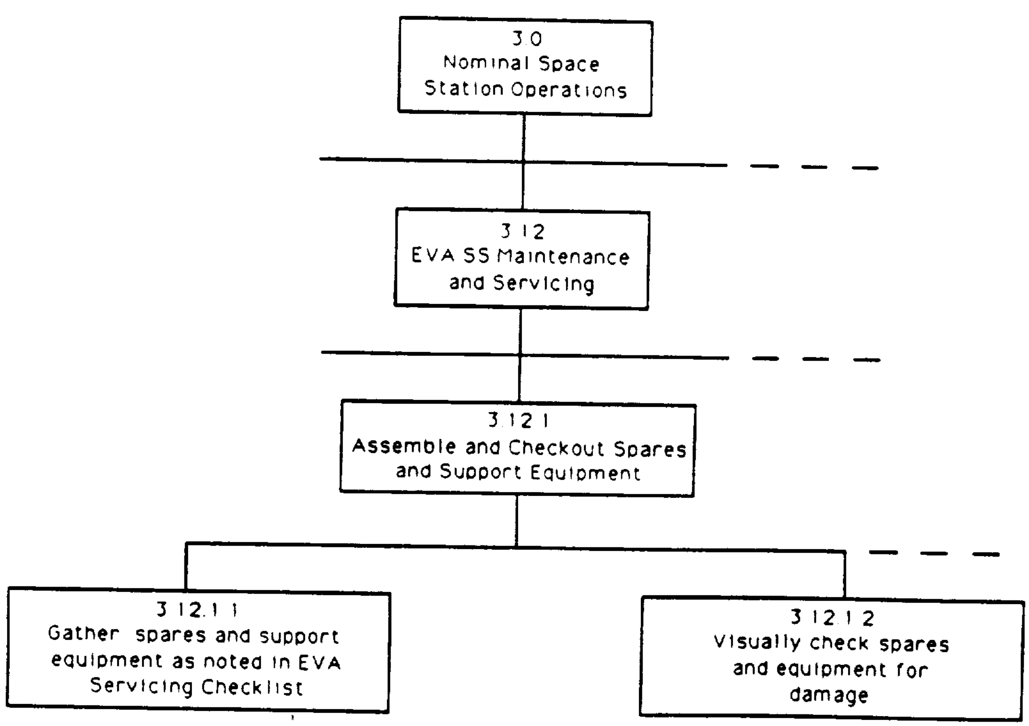
SAMPLE FLOW CHART OF TASK HIERARCHY



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OF POOR QUALITY

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FOCUS OF TASK ANALYSIS

- WHAT THE INDIVIDUAL DOES
- HOW THE INDIVIDUAL DOES IT
- WHAT THE INDIVIDUAL DOES IT WITH
- WHAT THE INDIVIDUAL DOES TO IT
- WHY THE INDIVIDUAL DOES IT

DG53/T K SMITH:3/16/89:TASK ANALYSIS

TRAINING OBJECTIVES ANALYSIS

- IDENTIFIES TERMINAL AND ENABLING TRAINING OBJECTIVES
- PRODUCT:

  OBJECTIVES HIERARCHY REPORT

INFORMATION DERIVED DURING THE TRAINING OBJECTIVES ANALYSIS

- DISCRETE BEHAVIORS REQUIRED TO PERFORM TASK
- CONDITIONS UNDER WHICH TASK IS PERFORMED

  e.g. DURING AN EVA, USING AN OPS CHECKLIST
- STIMULI OR CUES FOR PERFORMANCE

  e.g. GIVEN A CLASS III ALARM, GIVEN A TEMPERATURE READING OF 30 DEGREES C
- CRITICALITY OF PERFORMANCE

  e.g. DEGRADE SUCCESS OF MISSION, RESULT IN MAJOR DAMAGE OR INJURY

DG53/T K SMITH:3/16/89:TASK ANALYSIS

INFORMATION DERIVED DURING THE TRAINING OBJECTIVES ANALYSIS

- TIME TOLERANCE OF TASK

  e.g. SPECIFIC TIME FRAME CRITICAL TO SUCCESSFUL COMPLETION
- PROFICIENCY REQUIRED

  e.g. ACCOMPLISH TASK AT HIGHEST LEVELS OF SPEED OR ACCURACY, ONLY ABLE TO COMPLETE TASK WITH GUIDED ASSISTANCE
- FREQUENCY OF PERFORMANCE

  e.g. ONCE DURING A MONTH, EVERY DAY

DG53/T K SMITH:3/16/89:TASK ANALYSIS

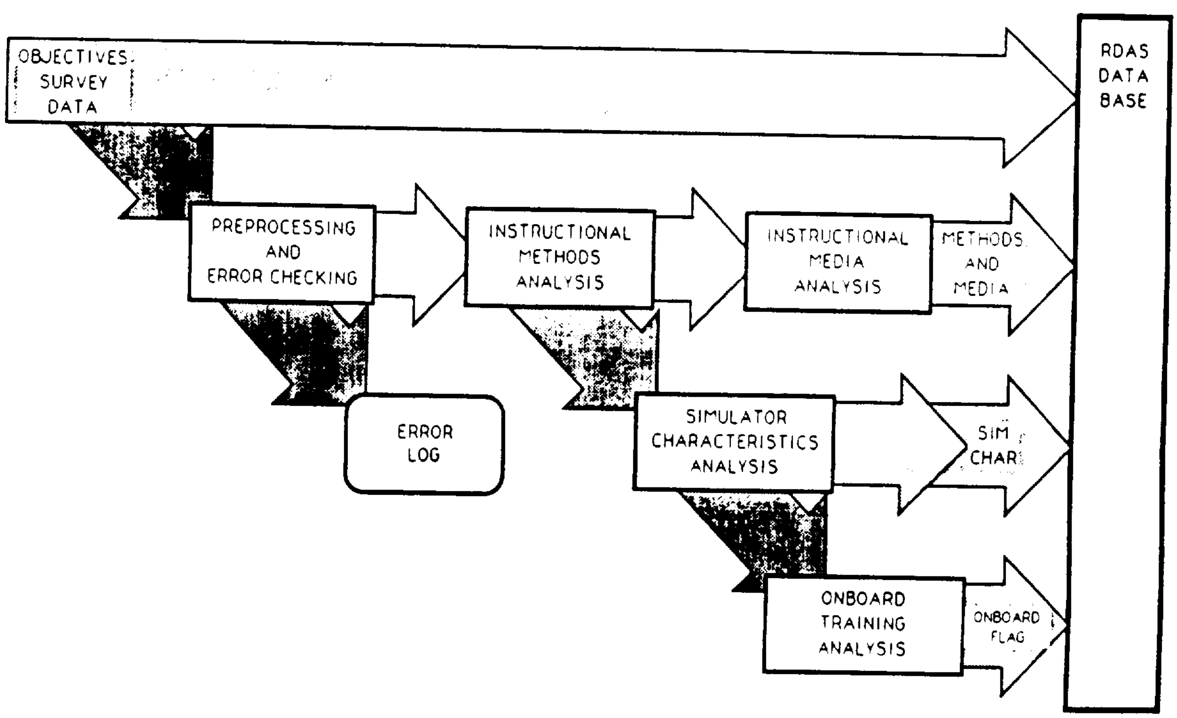
MEDIA SELECTION ANALYSIS

- IDENTIFIES GENERIC TRAINING MEDIA AND FACILITIES CHARACTERISTICS

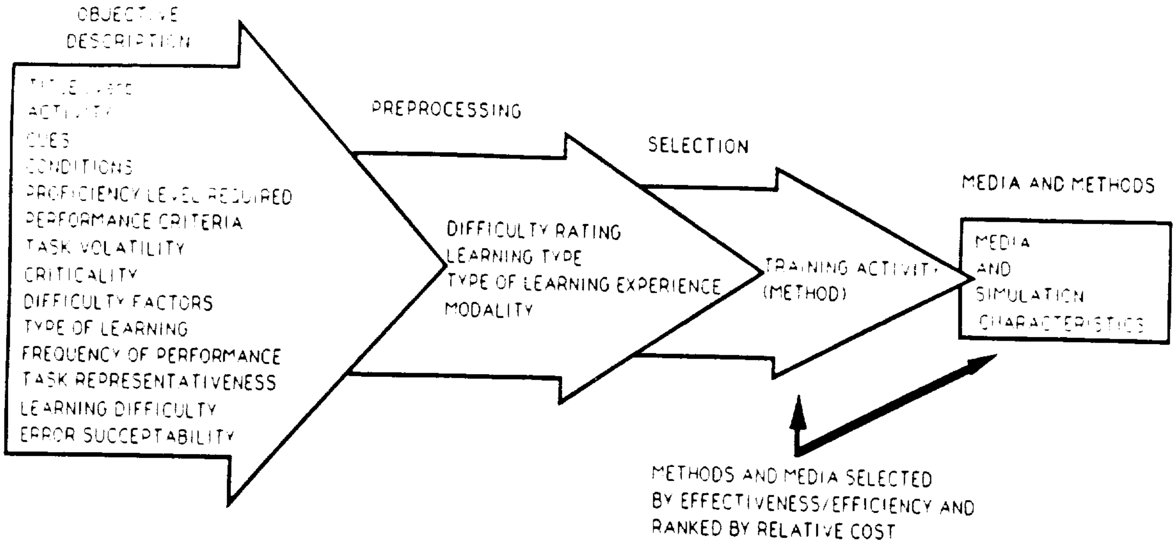
- PRODUCT:

  MEDIA ANALYSIS REPORT

MEDIA ANALYSIS FLOW



MEDIA SELECTION MODEL



DG53/A L WOOLDRIDGE:10/26/89:LOADING STUDY

CURRICULUM DESIGN ANALYSIS

- **IDENTIFIES TRAINING FLOW**
- **PRODUCTS:**
  - **COURSE OUTLINES**
  - **DETAILED LESSON LIST FOR EACH COURSE**
  - **COURSE PREREQUISITE CHART**
  - **LESSON PREREQUISITE CHART**

TRAINING FACILITIES MODEL

- EVALUATES OBJECTIVES IN TERMS OF THE TYPE OF TRAINING ACTIVITY (e.g. SIMULATION, CBT, FAMILIARIZATION BRIEFING) REQUIRED TO MEET THE OBJECTIVES
- IDENTIFIES THE TRAINING SUPPORT EQUIPMENT (e.g. NODE SYSTEMS TRAINER, MODULE SYSTEMS TRAINER) REQUIRED TO SUPPORT THE TRAINING ACTIVITY

TRAINING FACILITIES MODEL

<u>SSF TRAINING FACILITIES/DEVICES ARE SELECTED IN TERMS OF:</u>

*POSITIONS AVAILABLE FOR TRAINING **	
*SYSTEMS SIMULATED **	
EXTERNAL VISUAL SYSTEM CHARACTERISTICS (1,2)	[Scene Content,Field Of View]
INTERNAL PHYSICAL CHARACTERISTICS (1)	[Class I,II,III]
DISPLAY TYPE (1,3)	[ILLUMINATED,COLOR,LINE,INDICATOR]
GRAPHIC REPRESENTATION (1)	[PHOTOGRAPHIC,LINE GRAPHIC]
SIMULATION FIDELITY (1)	[A,B,C F]
SIMULATION RESPONSE/ STIMULATION CHARACTERISTICS (1)	[CHARACTERIZED,REPLICATE]
INSTRUCTOR SUPPORT CHARACTERISTICS (OPTIONAL) (1,2)	
INTEGRATED SIMULATION CAPABLE (1)	[TEAM TRAINING POSSIBLE]
*COST/HR OF INSTRUCTION **	

NOTES:

(1) Media selection model output/results
(2) List of examples provided separately
(3) Only applies when analyzing single control element
* Direct interpretation of data from survey instrument

PERSONNEL REQUIREMENTS MODEL

- NUMBER OF PEOPLE REQUIRING TRAINING AT ANY GIVEN TIME

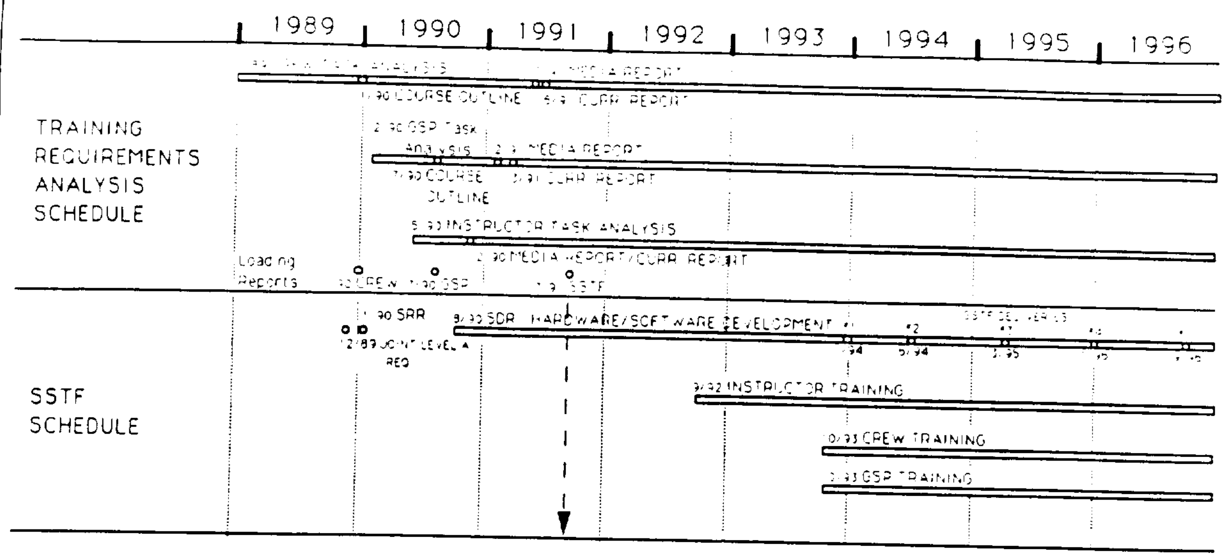
FACILITIES LOADING ANALYSIS

- IDENTIFIES THE EXTENT TO WHICH TRAINING FACILITIES WILL BE UTILIZED

THE FOLLOWING INFORMATION IS USED TO DEVELOP A LOADING STUDY:

- GSP AND CREW STAFFING REQUIREMENTS BY MONTH
- MAXIMUM NUMBER OF INSTRUCTION HOURS PER WEEK ALLOWED FOR EACH POSITION
- SPACE STATION TRAINING FACILITY CONFIGURATION
- MAXIMUM TIME AVAILABLE FOR EACH MEDIA TYPE
- CALENDAR LENGTH OF PROGRAM PHASE

TRAINING REQUIREMENTS ANALYSIS SCHEDULE



REALITIES OF THE SPACE BUSINESS

- PROPOSED USE OF SPACECRAFT CAN CHANGE OVER TIME
- COMPLEXITY OF SYSTEMS FLUCTUATES
- SUCCESS OF SYSTEMS INTEGRATION IS QUESTIONABLE
- OPERATIONAL CONSIDERATIONS ARE OVERSHADOWED BY SYSTEMS DESIGN
- STUDENT POPULATION CHANGES
  - •• FIRST GENERATION DOESN'T REQUIRE "ELEMENTARY SCHOOL"
  - •• SECOND GENERATION REQUIRES MORE PREPARATION FOR SIMULATORS

SUMMARY

- INITIAL STEP IN DETERMINING
  - TRAINING SYSTEMS REQUIREMENTS
  - TRAINING SIMULATION REQUIREMENTS
- PROVIDES DESCRIPTION OF HOW THE JOB IS PERFORMED
- IS THE FOUNDATION FOR DEVELOPING TRAINING OBJECTIVES, SELECTING INSTRUCTIONAL MEDIA AND STRATEGIES, AND DESIGNING LESSONS

SUMMARY

- BUILDING SSTF BASED ON KNOWLEDGE ACQUIRED FROM PREVIOUS PROGRAMS
- TRAINING REQUIREMENTS ANALYSIS HELPS TO IDENTIFY SIMULATION FIDELITY REQUIREMENTS
- TRAINING REQUIREMENTS ANALYSIS SHOULD HELP TO REDUCE THE EVOLUTIONARY TIME FOR DEVELOPING PART-TASK TRAINERS AND CURRICULUM

p. 14

Domain Analysis and Requirements Specification With Entity-Relationship Notation

Presented to

The Next Generation Simulators Workshop

NASA/Johnson Space Center
University of Houston - Clear Lake

Gary J. Cernosek
McDonnell Douglas
7 November 1989

Introduction

- Purpose

  Communicate experience with applying Entity-Relationship Diagrams (ERD) to requirements engineering

- Motivation - The need to respond to:
  - New programs (such as Space Station Freedom and Lunar/Mars studies)
  - New technologies (such as Ada, OOD, and domain analysis)
  - New programmatic initiatives (such as commonality, reuse, and evolutionary/open-ended programs)
- Objectives - Help answer the following questions:
  - Why should we investigate new approaches to requirements specification, in general?
  - Specifically, how can we apply ER notation to the requirements development process?
  - What are the benefits, limitations, and directions of these developments?
- Scope of this presentation

  Focused on requirements analysis, but overall method is designed to integrate into design and implementation

Outline

- Background
- Methodology Development Overview
- Example: Applying ERDs to analyzing a Space Station plume impingement problem (Appendix)
- Lessons Learned
- Current Directions

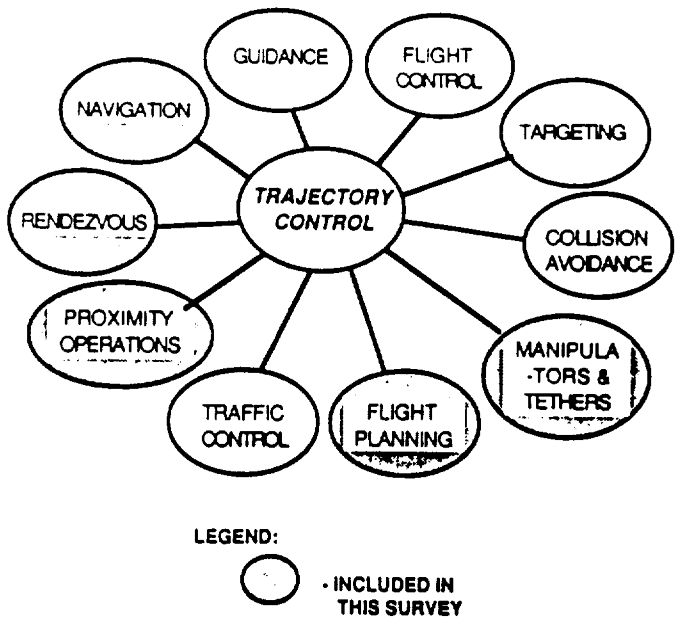
Background

- Space Station Freedom Program and Ada
- NASA's commonality and reuse goals (Cernosek, 1989a)
- McDonnell Douglas - Houston: Ada and Software Engineering Initiative (1987)
  - Statement of commitment to help develop NASA's Ada standard
  - Capital investment to help share initial risks (Rational Environment procurement)
  - Practical methods for transitioning to Ada environments (Cernosek, 1989b)
- NASA-JSC / MPAD, Common Model Development (CMD) project (1987, basis for this presentation)

Drivers for the CMD Methodology

- C. McKay/UHCL - Conceptual models for computer systems and software engineering
  - Development Environment
  - Integration Environment
  - Operations Environment
- McDonnell Douglas' Common Ada Missile Package - CAMP (McNicholl et al, 1986) - *Domain Analysis:*
  - Domain Definition - scope and boundary assessment
  - Domain Representation - representative sample of existing applications
  - Commonality Study - common objects, operations, and structures to consider for reuse
- NASA Goddard Space Flight Center, *Generalized Object-Oriented Development* (GOOD) (Seidewitz and Stark, 1987)
- G. Booch (1983, 87) - Software engineering, Ada, and the need to engineer reuse into the process and products

MPAD Analysis Domains Considered



- **A wide variety of mission planning and analysis domains were considered for the CMD effort.**

Domain Selection Criteria and Rating Results

	CRITERIA	Rendezvous	Navigation	Prox Ops	RMS	FLIGHT PLANNING Ascent	FLIGHT PLANNING Orbit	FLIGHT PLANNING Descent
Highest Importance	Experts Available	0	+	+	0	+	+	-
	Documentation	-	0	0	-	-	-	-
	Space Station Applicability	+	+	+	+	-	+	-
	Plans for the Domain	0	+	+	+	-	-	-
Medium	Modularity	-	0	0	0	0	-	0
	Degree of Automation	0	+	+	0	0	-	0
	Complexity and Size	0	-	0	0	-	0	-
Lowest Importance	Maturity of Domain	+	+	+	-	+	+	+
	Computer Systems, HW and SW	-	+	0	0	0	-	-
	Outside Sources of Information	0	+	0	0	-	-	-

- ***Proximity Operations*** **was the domain selected for prototyping.**

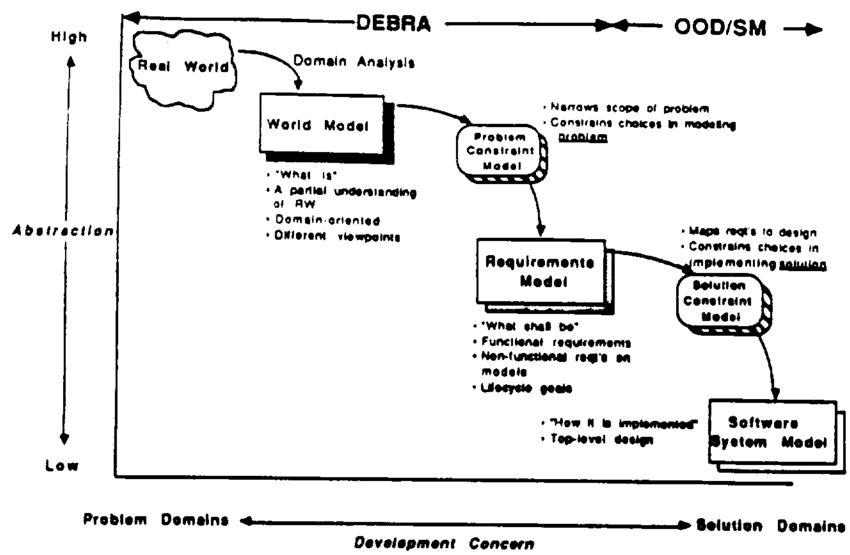
Goals for a Commonality-Oriented Methodology (Cernosek, Pribyl, et al, 1987a)

1. Completely define the problem statement
2. Consistently define the problem statement
3. Correctly define the problem statement
4. Distinguish between true requirements, unduly constraining design decisions, and useful design suggestions
5. Enhance communication between software users and software developers
6. Maximize the "abstractness" of the problem statement in such a way that other projects can recognize common items
7. Produce self-describing requirements in a taxonomy that complements the existing domain's application requirements
8. Facilitate a search of the existing domain for "reusable" requirements prior to proceeding to design and implementation
9. Provide for natural mapping to object-oriented design in a manner which facilitates traceability

CMD Task Products and By-Products

- CMD Delivery Documents - April-October 1987 (see references)
  - Domain Survey and Selection Document
  - Domain Analysis Document
  - Top-Level Design Document
  - Methodologies Document
- UHCL Master's Thesis - G. Cernosek, *A Semantic Modeling Approach to Integrating Requirements Analysis and Object-Oriented Development* (May 1988)
- Domain- and Entity-Based Requirements Analysis (DEBRA)
  - Domain-oriented to manage reuse of requirements and designs products
  - Entity-oriented to integrate better with OOD and Ada
- Object-Oriented Development with Semantic Modeling (OOD/SM)
  - Addresses shortcomings of various Booch-like approaches to OOD
  - Semantic modeling with ERDs help fill in the "semantic gap" left by strictly object-oriented techniques

Integrating Lifecycle Abstractions With ER Models



- Any partitioning of the lifecycle is arbitrary => criteria is needed
- Separate ER models are used for domain analysis, requirements specification, and OOD
- Transition models are used to facilitate traceability and capture rationale of modeling decisions

Lessons Learned - On the use of ERDs for Requirements Analysis

- Advantages
  - Excellent for human communication
  - Assists in domain analysis and lifecycle reuse
  - Captures modeling decisions and assumptions
  - Maps well to OOD and Ada packages
- Limitations
  - ERDs capture <u>static</u> semantics - dynamics and temporal issues can be inferred, but must be expanded via other notations (e.g., STDs, DFDs)
  - Still not enough practical experience to assess full applicability
- Shortcomings due to schedule
  - Carried development only through preliminary design
  - Evolutionary development needed to assess reusability at requirements and design levels

On Requirements Modeling in General

- Case study: OMV Proximity Operations Simulation (O'Donnell and Marchand, 1989)
  - Formal requirements modeling using Structured Analysis w/real-time extensions (ERDs not used)
  - Tool support via CADRE team*work*™
- Advantages
  - Customer acceptance
  - Automates tedious manual efforts
  - Consistency and completeness checks
  - Especially appropriate for "stable" projects =>
    - - Long-term funding secure (enough to realize benefits from early lifecycle load-balancing
    - - Completion-form style of contracting (where efficiency is a must)
- Limitations
  - Cannot justify cost of maintaining models in some work environments (e.g., engineering analysis tool development)
  - Hard to synchronize code and model maintenance

Future Directions

- Reverse engineering
- Executable requirements specification languages
- <u>Ada</u> as a requirements specification language -- debatable
  - Has been proposed by others
  - "Ada is <u>not</u> powerful enough, but..."
    - - Package mechanism supports what-how relationship between specification and implementation
    - - Strong typing provides completeness and consistency checking to a large degree
    - - Inherent prototyping nature of engineering analysis environments could significantly benefit
    - - Single-point maintenance realized (package spec is focal point for engineering decisions)
  - Hybrid approach possible:
    - - Requirements and design modeling for <u>initial</u> effort
    - - Prototyping phase (until stable baseline achieved)
    - - Revisit modeling for post-product documentation (reverse engineering)

Related and Supporting Efforts

- In the Industry:
  - Shlaer/Mellor's *Object-Oriented Systems Analysis*, Project Technology, Inc.
  - CADRE Training Series for team*work*™ tool support
  - EVB Software Engineering, *Object-Oriented Requirements Analysis*
  - Peter Coad and Ed Yourdon, *OOA - Object-Oriented Analysis*
  - Others

- At MDSSC-ESD
  - Ada Simulation Development System (ASDS)
  - Common Models Working Group (COMWG)
  - Operations Planning and Analysis System (OPAS)

Acknowledgements

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The Common Model Development Team

Ed Monteiro-Knight, Lead

Terry Alford	Sam Juliano
Barry Cameron	Bill Mattison
Gary Cernosek	Bill Pribyl
Russ Helbig	David Roman
Harold Ipolyi	Bill Watkins

References

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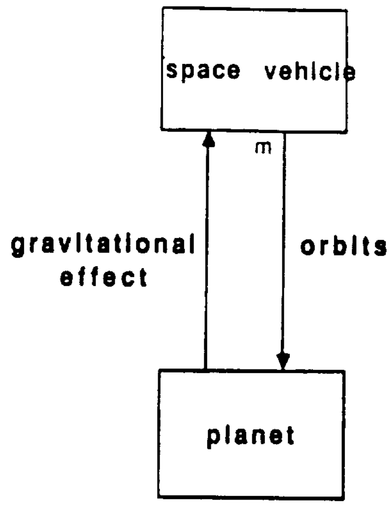
Appendix

Applying ERDs to analyzing a Space Station plume impingement problem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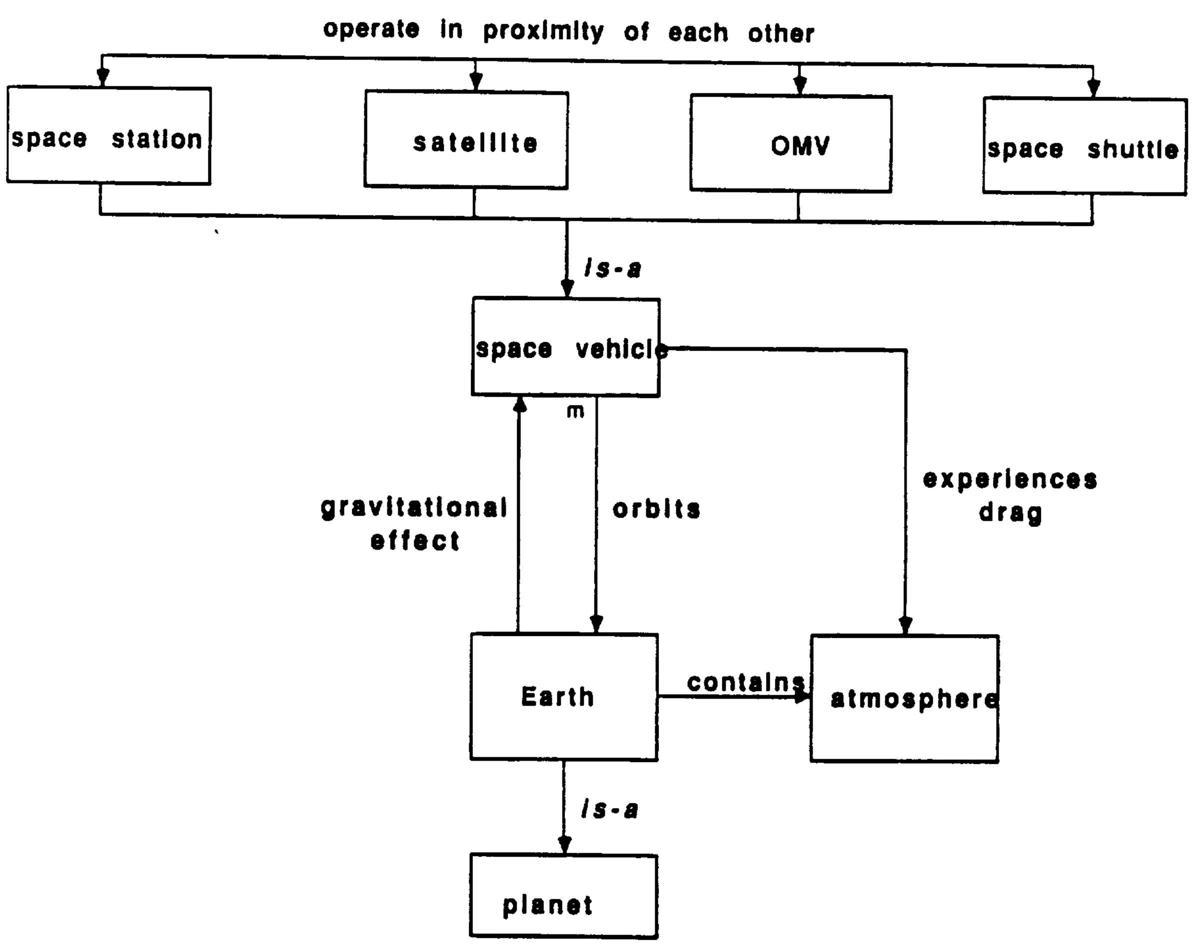
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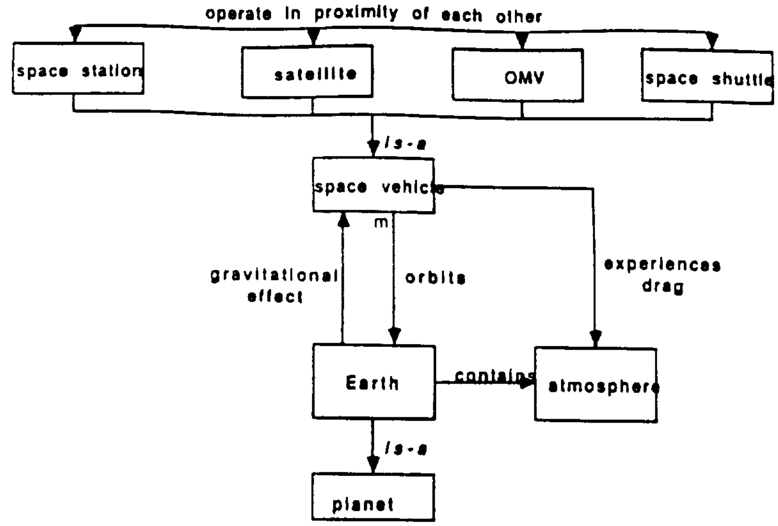

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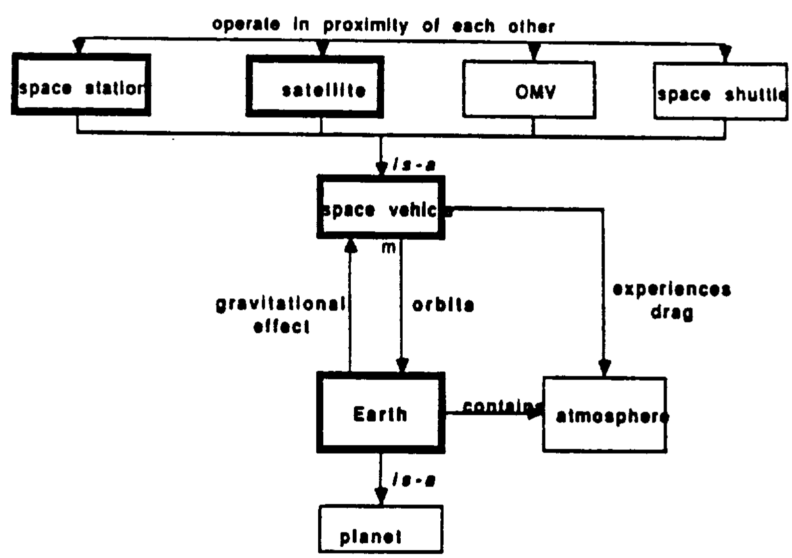

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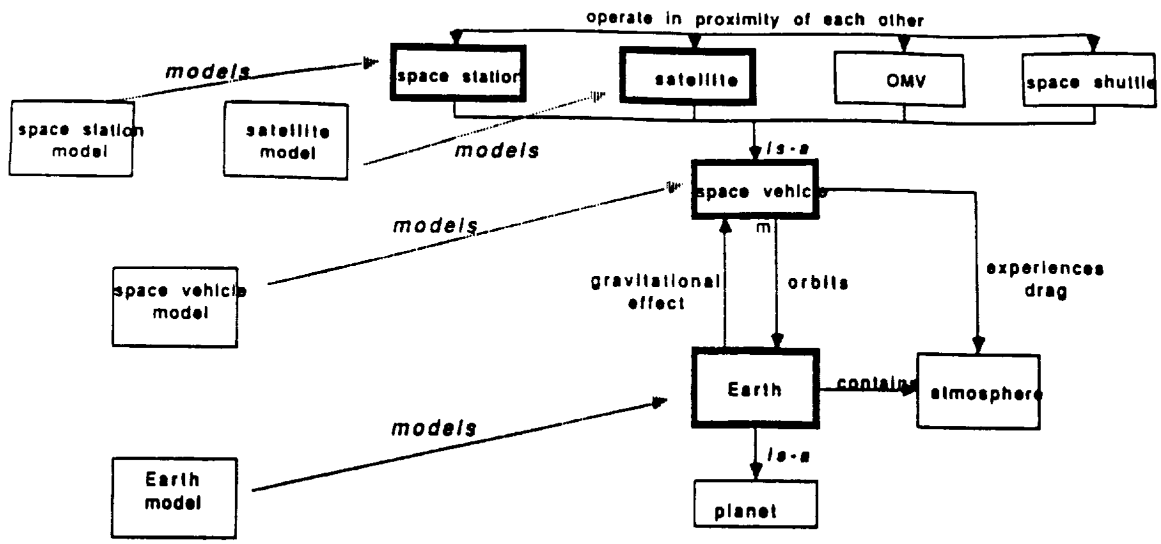

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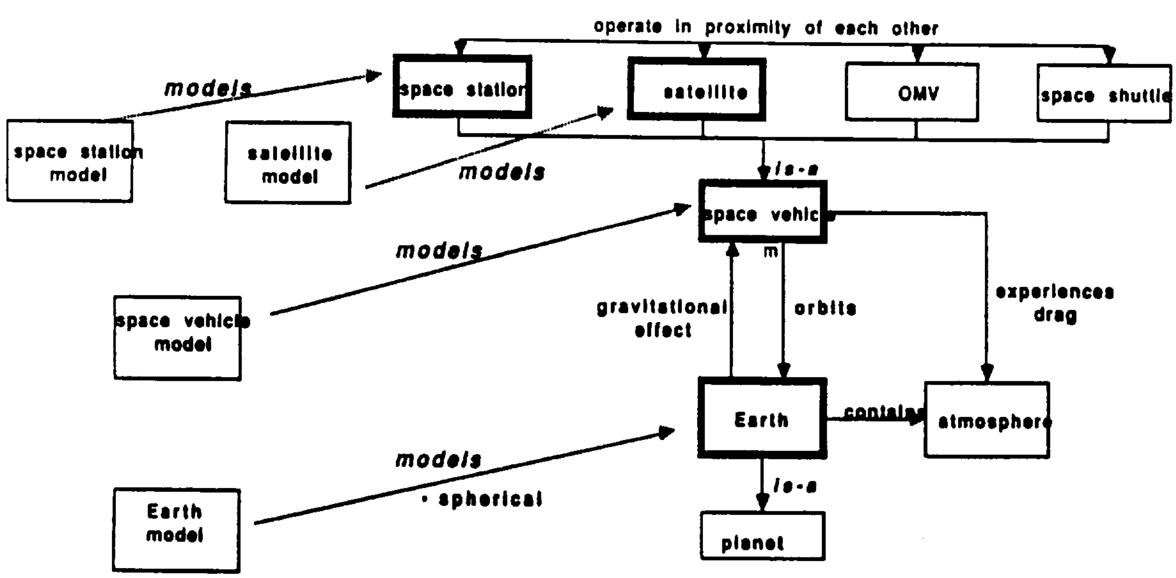

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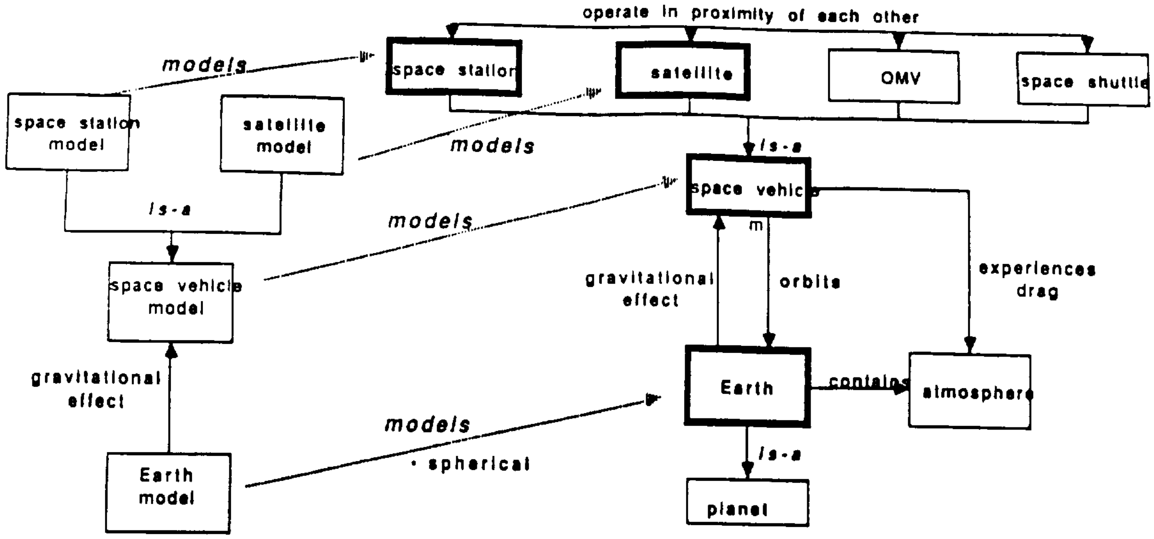
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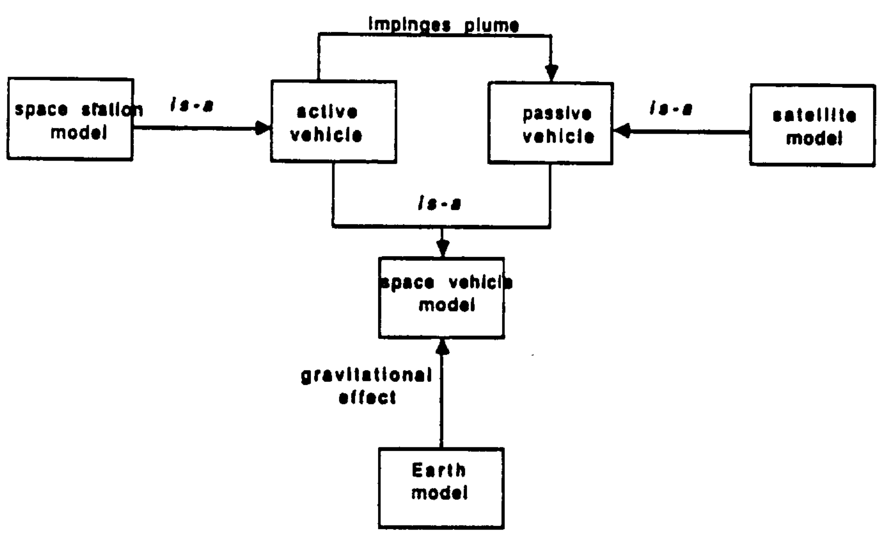
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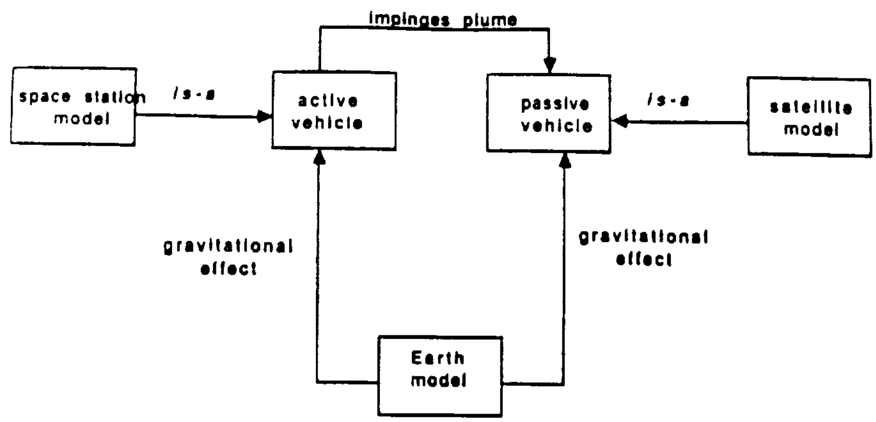
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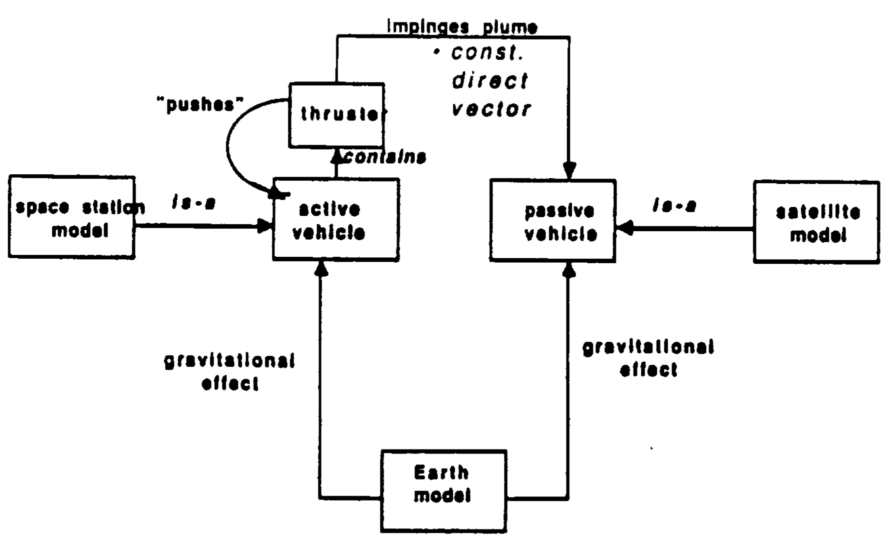
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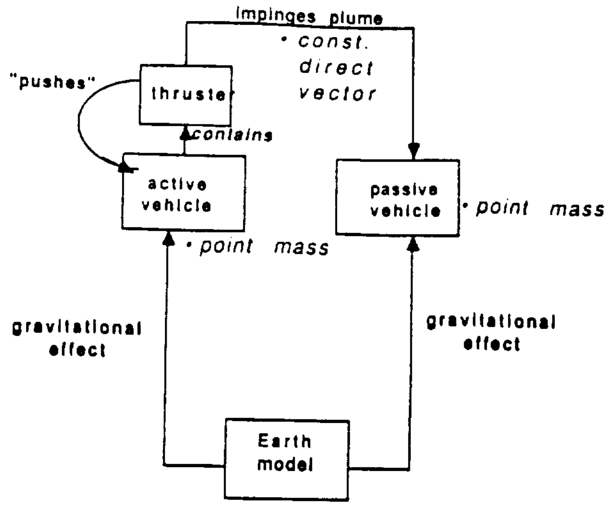

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SIMULATION REQUIREMENTS IN INTEGRATION FACILITIES

D. Warner
MDSSC
7 November 1989

Simulation Requirements In Integration Facilities

CONTENTS

- Drivers For Simulation Requirements
- Types Of Simulation Requirements
- Derivation Of Simulation Requirements From Facility System Requirements
- Standards
- Perspective On Simulation Requirements From Several Integration Facilities

SIMULATION REQUIREMENTS IN INTEGRATION FACILITIES

DRIVERS FOR SIMULATION REQUIREMENTS

- Characteristics Of Integration Facility
  - Standalone Versus Integrated Operations
  - Capability To Roll Hardware In And Out
  - Concurrent Testing
  - Functionally Equivalent Hardware Versus Actual Physical Hardware
  - Support of Anomaly Resolution

SIMULATION REQUIREMENTS IN INTEGRATION FACILITIES

CATEGORIES OF SIMULATION REQUIREMENTS

Specific Models	
Common Model Requirements	**Specific Model Requirements**
Configuration Data	Models required
Modularity	Functions
Fidelity	Interfaces
	Performance and Fidelity

SIMULATION REQUIREMENTS IN INTEGRATION FACILITIES

CATEGORIES OF SIMULATION REQUIREMENTS

Computer System and Special Simulation Hardware	
Computer System	**Special Simulation Hardware**
Computational Capacity	Simulation Interface Buffer
I/O Capacity	Signal Conditioning Equipment

SIMULATION REQUIREMENTS IN INTEGRATION FACILITIES

DRIVERS FOR SIMULATION REQUIREMENTS

- Types Of Testing Performed
  - Interface
  - Functional
  - Performance

- Level Of Testing Performed
  - Subsystem
  - System
  - Multi-System

SIMULATION REQUIREMENTS IN INTEGRATION FACILITIES

CATEGORIES OF SIMULATION REQUIREMENTS

Simulation Services		
Pre-Test Setup	**Simulation Execution Control**	**Post-Test Processing**
Test Script Definition	Simulation Executive	Data Delogging
UIL Script Definition	Time Simulation	Report Generation
Object Database Definition	Simulation Synchronization	Data Reduction
Simulation Identification and characterization	Model Execution Control	Interactive Data Analysis
	Initialization	
Data logging Definition	Checkpointing	
Simulation Initialization Data Definition	Data Logging	
Test Configuration Definition	Fault Insertion	

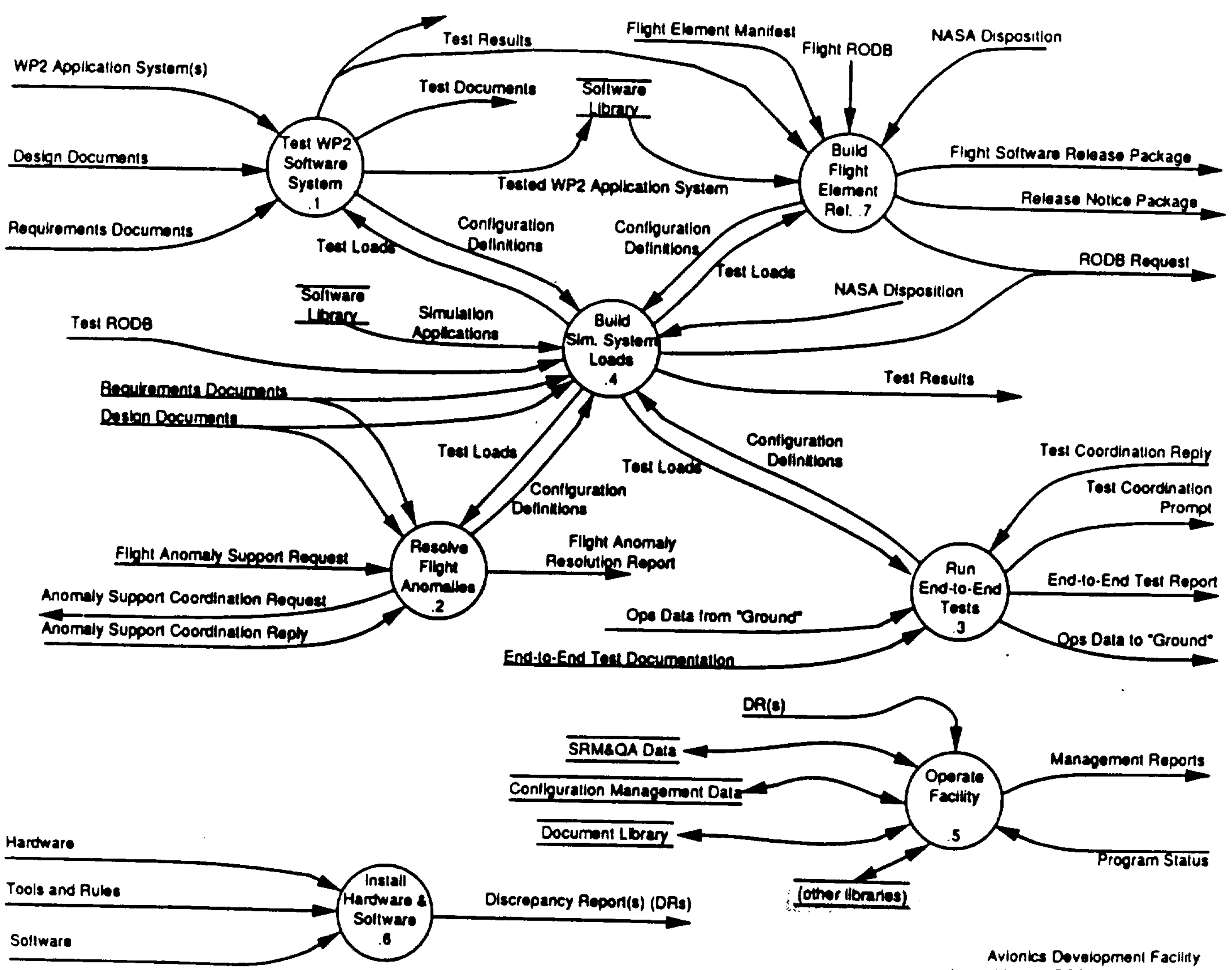
SIMULATION REQUIREMENTS IN INTEGRATION FACILITIES

REQUIREMENTS FLOW DOWN

TOP LEVEL SYSTEM REQUIREMENTS TO SIMULATION REQUIREMENTS

- **Analysis Of System Requirements For Integration Facility Should Lead To Derivation Of Requirements For Simulations**

- **Simulation Requirements Are No Different Than Other Components Of A System's Architecture**
  - **No Magic Mirrors Required**
  - **But, Rather The Result Of A Rigorous Analysis Process**
    - **Structured Analysis Techniques Applicable**
    - **Synthesizing Requirements**
    - **Trade Studies**



Avionics Development Facility
derived from MDSSC / IBM analysis team

SIMULATION REQUIREMENTS IN INTEGRATION FACILITIES

REQUIREMENTS FLOW DOWN

TOP LEVEL SYSTEM REQUIREMENTS TO SIMULATION REQUIREMENTS

- The Evolution of Some Simulation Requirements Appear (Simulation Services) To Parallel System Requirements Derivation For The Facility
  - Perceived Need For These Requirements Early On
  - Often Before We Understand What Facility Mission Is
  - Must Avoid Whenever Possible
- The "When" Is Surely Just As Important As The "How"

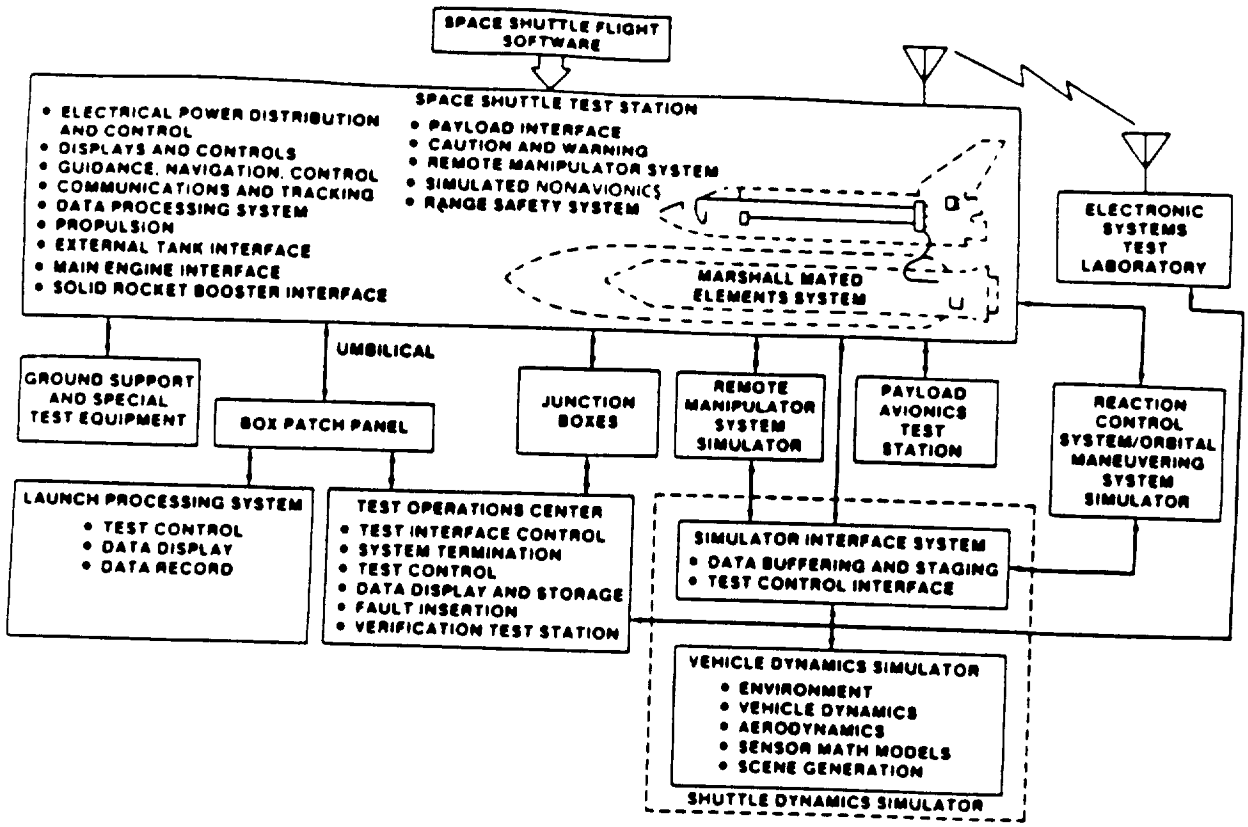
SIMULATION REQUIREMENTS IN INTEGRATION FACILITIES

SIMULATION STANDARDS

- Extremely Important For Simulation Development
- The Appropriate Simulation Requirements Can Be Derived But We Will Still Fail
  - Will Not Be Able To Integrate Simulations
    - Language
    - Interface
    - Simulation Modularity

SIMULATION REQUIREMENTS IN INTEGRATION FACILITIES

SHUTTLE AVIONICS INTEGRATION FACILITY



SIMULATION REQUIREMENTS IN INTEGRATION FACILITIES

AVIONICS DEVELOPMENT FACILITY

- **Top Level Requirements**
  - **Integrate SSF WP2 HW and SW That Interfaces With Global Bus**
  - **Global Bus/Shared Resource Testing**
    - **Functional/Performance**
    - **Stress**
    - **Redundancy**
  - **Support Flight Anomaly Resolution**
  - **Assembly Of WP2 Software Loads**
  - **Verification of WP2 Software Loads**
  - **Perform End-To-End Testing With SSCC and ESTL**
  - **Develop/Verify WP2 SSF Software Installation Procedures**

SIMULATION REQUIREMENTS IN INTEGRATION FACILITIES

IMPLEMENTATION OF SIMULATION REQUIREMENTS

FROM THE PERSPECTIVE OF SEVERAL INTEGRATION FACILITIES

- Shuttle Avionics Integration Facility (SAIL)
- Space Station Freedom Avionics Development Facility

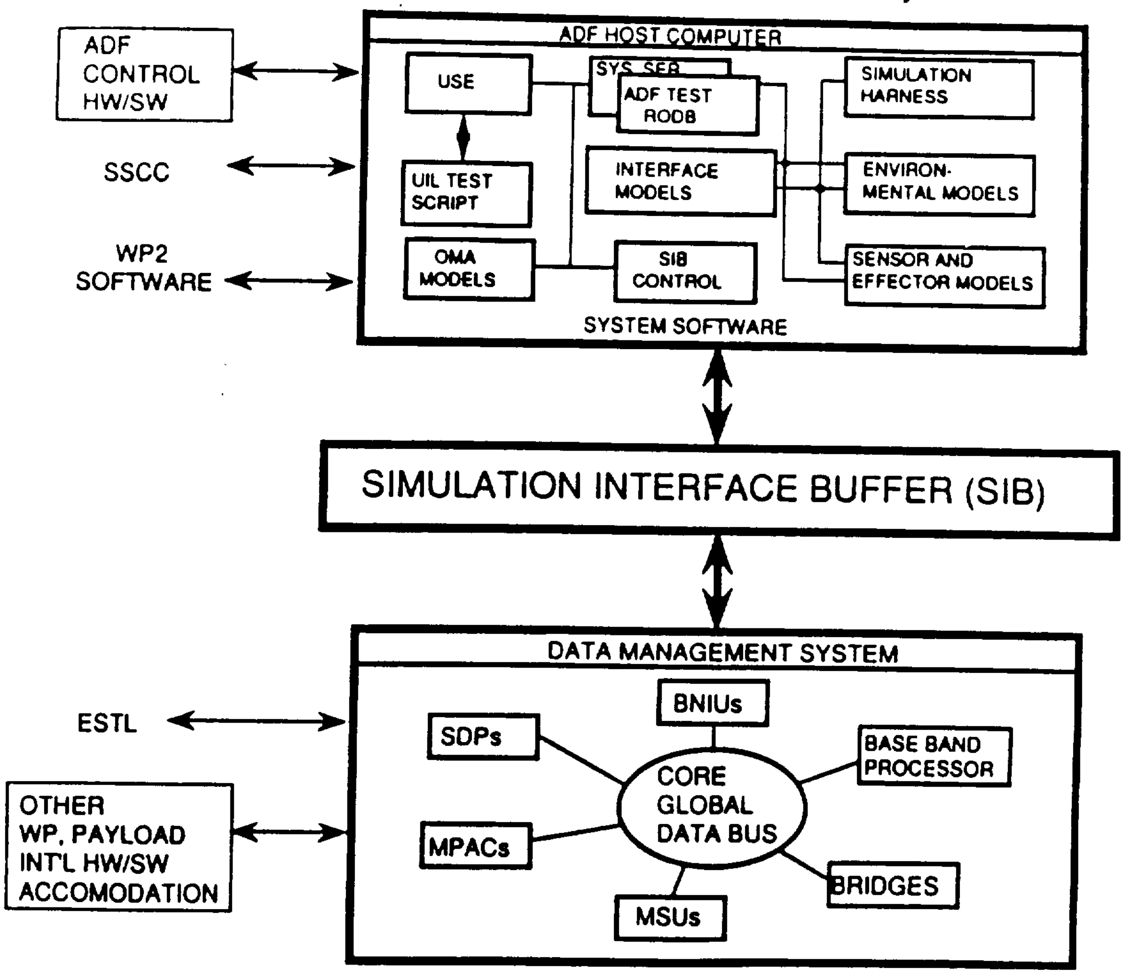
SIMULATION REQUIREMENTS IN INTEGRATION FACILITIES

SHUTTLE AVIONICS INTEGRATION FACILITY

- Top Level Requirements
  - Perform System And Mission Verification Testing
    - Avionics Hardware
    - Avionics Software
    - Related Flight Hardware(Or Simulations Of Hardware)
    - Flight Procedures
    - Ground Support Equipment
  - Provide Support capability for Shuttle Mission Phases
    - Prelaunch And Ascent Phases
    - On-orbit Operations
    - Entry Through Rollout

SIMULATION REQUIREMENTS IN INTEGRATION FACILITIES

AVIONICS DEVELOPMENT FACILITY



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ABSTRACT = Topics addressed are: (1) attempt at object-oriented requirements analysis using traditional CASE tools; (2) modeling and analysis of aerospace system components using EASY5 (engineering analysis system 5); (3) the role of training requirements analysis in defining simulation requirements for training; (4) domain analysis and requirements specification with entity-relationship notation; and (5) simulation requirements in integration facilities.

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